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Omaha District

MISSOURI RIVER RECOVERY PROGRAM
2009 SPRING PULSE AND RISES

DRAINAGE MONITORING AND EVALUATION

HYDROLOGIC ENGINEERING BRANCH
ENGINEERING DIVISION
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Executive Summary

Spring pulse releases for the benefit of the endangered pallid sturgeon were planned for March and May 2009 to mimic historic natural spring rises that occurred on the Missouri River before the closure of the main stem dams. The March spring pulse from Gavins Point Dam was not released in 2009 due to high downstream flows and the possibility of flow-limit violations. A 6.1 -kcfs May spring pulse was released in 2009.

The May spring pulse was monitored at 44 sites along the Missouri River. Nineteen of these were interior-drainage sites that were monitored for possible socioeconomic impacts to landowners. Socioeconomic impacts include gate closures, pumping, and overbank flooding. To help identify socioeconomic impacts, berm and field elevations were surveyed near the installed gages in March 2009 to better characterize possible overbank flooding. The location of the created spring pulse in the record was determined through the use of travel times from Gavins Point Dam.

The 2009 May spring pulse created no socioeconomic impacts at any of the monitored sites.

A flow attenuation rate was estimated for the May 2009 spring pulse using observed flow records at eight main stem gages along the Missouri River. The 6.1-kcfs spring pulse was estimated to attenuate at a rate of 1.1 kcfs for every 100 river miles in May 2009. The observed May 2009 spring pulse was 1.5 kcfs at Kansas City, MO and is estimated to have attenuated by 77%. Similar results were determined for the 4.5-kcfs March 2008 spring pulse in the 2008 monitoring report. The March 2008 spring pulse attenuated at a rate of 1.1 kcfs for every 100 river miles and was not distinguishable by Kansas City, MO.

A stage attenuation rate was also estimated for the May 2009 spring pulse. In general, the 1.8-ft May 2009 spring pulse attenuated at an approximate rate of 0.4 ft for every 100 river miles. This analysis was also completed for the March 2008 and May 2006 spring pulses. The 1.5-ft March 2008 spring pulse attenuated at a rate of 0.4 ft for every 100 river miles, and the 2.7-ft May 2006 spring pulse attenuated at a rate of 0.3 ft for every 100 river miles.

Flow reductions were made from dams tributary to the Missouri River to eliminate the created spring rise below Kansas City, MO. This reduction lowered the stage of the created spring rise. A stage change due to the created spring rise is still visible below Kansas City, MO, but the created spring rise is effectively reduced in elevation.

The effects of additional natural-spring rises were monitored at each site to help quantify flows that would result in landowner impacts. Where socioeconomic impacts (i.e. gate closures, pumping, and overbank flooding) did occur due to these flows, the duration of the impacts and impact-flow thresholds were estimated. Impact-flow thresholds are flows in the Missouri River at the river mile of the impacted site when the stage over the sensor of the gage becomes high enough to cause gate closures, pumping, or overbank flooding at a site.

The durations of high flows in the Missouri River in 2009 were much shorter than they were in 2008. The 2008 record experienced a long duration large rise that began in late May and continued through mid-June or early July depending on the river location. In contrast, the 2009 record experienced several shorter duration rises scattered throughout the record.

Table 1 summarizes the results for the 2006, 2008, and 2009 monitoring periods. Natural spring rise results are not shown for 2006 because only the spring pulse was monitored that year. Figure E1 shows the sites impacted by natural spring rises in 2009 and 2008 plotted

by their RM locations along the Missouri River and the estimated flows in the Missouri River at the sites that resulted in gage closures.

Table E1 – Results Summary

	Monitoring Period		
	2009	**2008**	**2006**
No. Interior Drainage Sites Monitored	19	16	7
Created Spring Pulse Released from Gavins Point Dam			
No. Interior Drainage Sites Impacted by Created Spring Pulse	0	0	0
Natural Spring Rises			
No. Interior Drainage Sites with Impacts	11	11	-
Days of Impacts	0.5 to 12	6.7 to 39	-
No. Interior Drainage Sites with LS Flooding	2	3	-
Days of LS Flooding	1.8 to 2.7	9 to 11	-
No. Interior Drainage Sites with RS Flooding	2	2	-
Days of RS Flooding	0.5 to 1	20 to 24	-
No. Interior Drainage Sites with Gate Closures	8	11	-
Days of Gate Closures	0.1 to 11	6.7 to 39	-
No. Interior Drainage Sites with Pumping	3	4	-
Days of Pumping	0.2 to 12	15 to 39	-

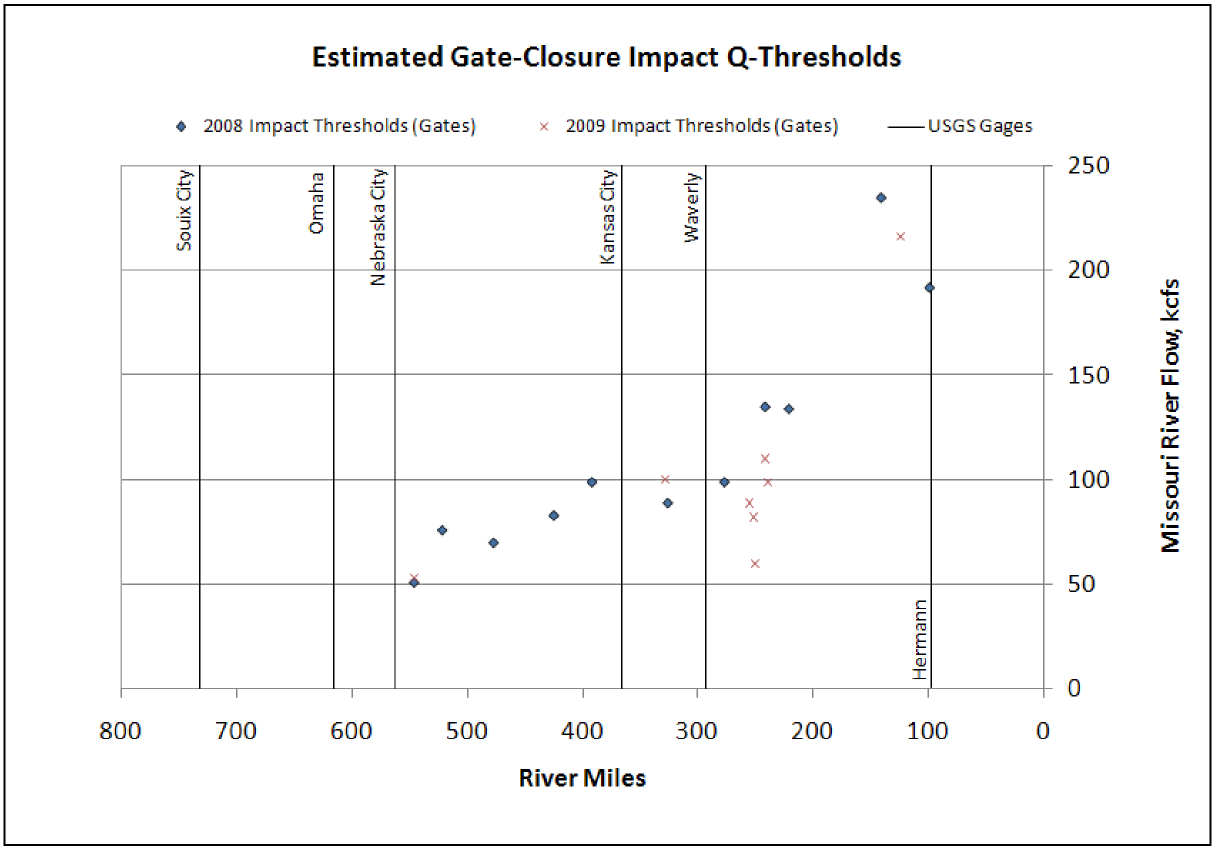

Figure E1 – Natural spring rise gate-closure flow thresholds, 2008 & 2009

Definitions and Acronyms

Adverse slope

Slope of a channel or drainage culvert in which water must flow uphill. In the case of a drainage culvert, the inlet of the culvert is lower in elevation than the outlet.

Attenuation

The decrease in the peak flow of a discharge hydrograph as it travels downstream. Attenuation is due to storage and friction in the river channel.

Automatic gage

USGS or USACE gages capable of gage-to-satellite transmission through a data collection platform (DCP). The Omaha, Nebraska City, and Kansas City gages used in this report are examples of automatic gages.

CMP – Corrugated metal pipe

Created spring pulse

Increase in discharge released from Gavins Point Dam in March and May to benefit the endangered pallid sturgeon and mimic the historic bimodal natural pulses that occurred before the closure of the Missouri River main stem dams.

Created spring rise

Increase in stage and flow at a particular location along the Missouri River in response to the created spring pulse released from Gavins Point Dam.

CRP Elevation

The CRP elevation is the construction reference plane. The CRP elevation is the approximate water surface profile for a 75% exceedance flow. The CRP differs from location to location along the Missouri River and is updated to account for new flow data and changes in channel geomorphology.

Data logger

Sensor installed into the pipe casing at each supplemental site that records pressure differences. The pressure data are downloaded and processed to obtain water surface elevation.

DCP – Data collection platform

Instrumentation within an automatic gage that collects stage and flow data at a site and then transmits them to satellite.

DLD – Drainage and Levee District

DS – Downstream

Full Record

The full monitoring record from March 1, 2009 through September 26, 2009.

Gage-sensitivity threshold

Flow in the Missouri River at the river mile of a site when the water elevation at the gage becomes high enough for the gage sensor to become submerged (Figure i).

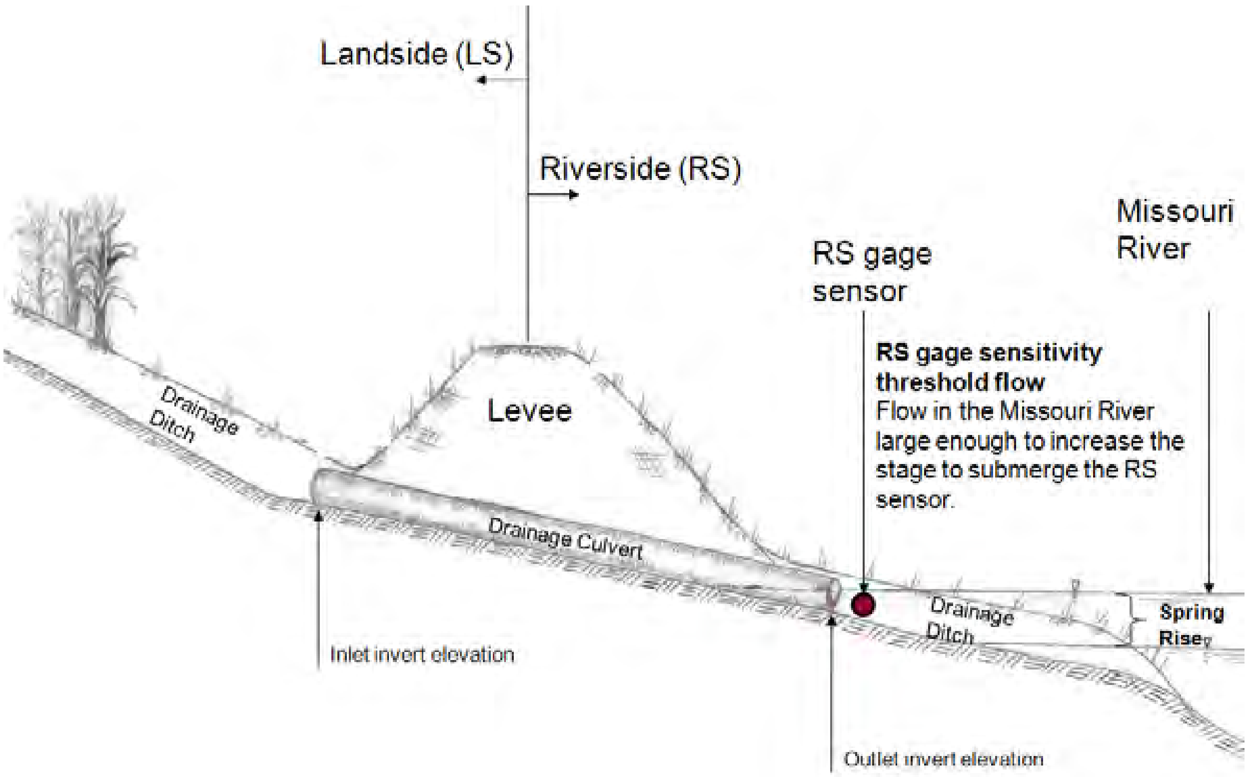

Figure i – Monitoring site illustration

Impact-flow Thresholds

Flow in the Missouri River at the river mile of the site when the stage over the sensor of the gage becomes high enough to cause gate closures, pumping, or overbank flooding at the site.

Inlet Invert Elevation

The elevation of the bottom of the culvert inlet on the landside of the drainage structure and levee. See Figure i.

Interior-drainage monitoring site

Monitoring site located off the main stem of the Missouri River with gages installed in a drainage ditch or on a levee.

Interpolated Flow

Estimated flow directly at a site calculated from the lagged flow records of the closest upstream and downstream automatic Missouri River gages. Flow records are lagged forward and backward in time based on either navigation or bankfull travel times and the flow at the site interpolated by river mile.

L – Left

Left bank of the Missouri River.

LD – Levee District

LS – Landside

Side of the monitored site protected by the levee. See Figure i.

MD – Main Ditch

Used to differentiate between the ditch flowing through the main levee of a site and the side ditch contributing flow to the main ditch.

MR – Missouri River

Natural spring rises (NSR)

Rises in the Missouri River other than that created by the spring pulse release for the endangered pallid sturgeon. Increases in Missouri River stages and flows due to precipitation runoff.

NAVD 88

North American Vertical Datum of 1988.

NGVD 29

National Geodetic Vertical Datum of 1929.

NSR

See *Natural spring rises (NSR)* definition.

Observed Stage Change or Peak Flow

When ‘observed’ is used to describe either the change in stage produced or the peak flow at a gage, it means the value provided was measured from the gage data and not estimated through a calculation based on a general regression equation.

Outlet invert elevation

The elevation of the bottom of the culvert on the riverside of the drainage structure and levee. See Figure i.

Partial Spring Rise

Used when the spring rise captured by a supplemental gage is affected by the sensitivity threshold of the gage. In the case of gages directly on the Missouri River, the full created spring rise is captured. However, for gages on drainage channels tributary to the Missouri River, only a portion of the created spring rise (called the partial spring rise) is often captured due to the elevation difference between the gage and the Missouri River. See Figure ii for an illustration.

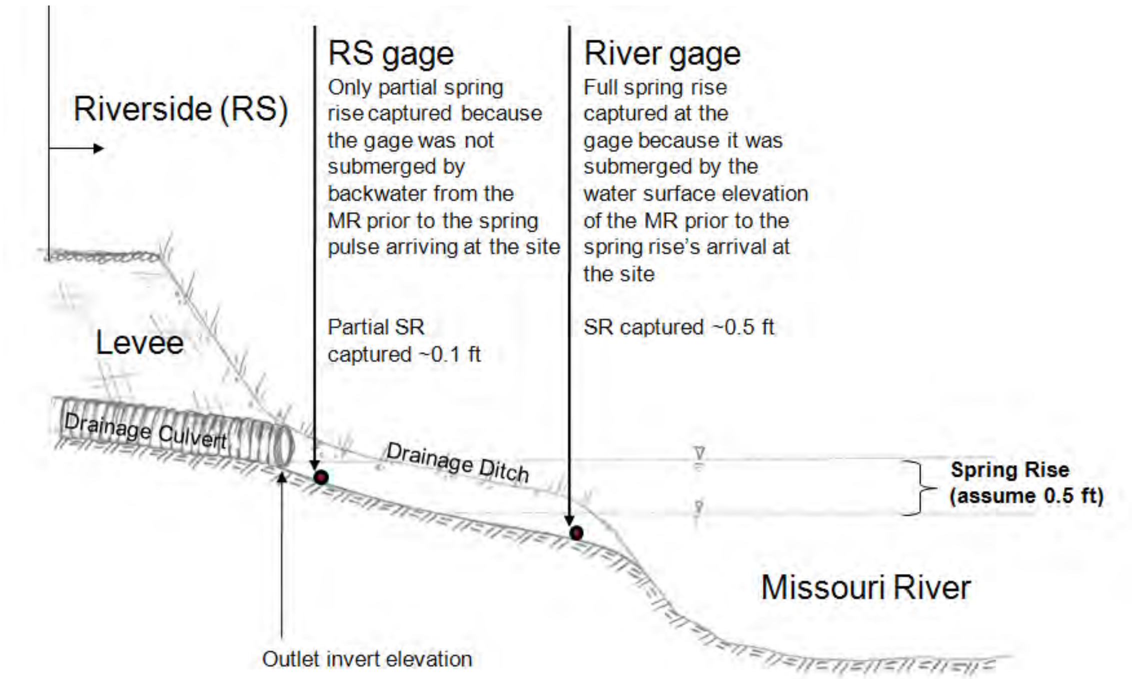

Figure ii – Partial spring rise

R – Right

Right bank of the Missouri River.

RS – Riverside

Side of the monitoring site closest to the Missouri River and not protected by the levee. See Figure i.

SD – Side ditch

Ditch emptying into the main ditch of a site. The main ditch empties directly into the Missouri River. The side ditch empties into the main ditch and then into the Missouri River.

Socioeconomic Impacts

Socioeconomic impacts included gate closures, pumping, and overbank flooding.

Supplemental gages

Temporary gages installed to monitor the effects of the spring pulse on drainage and its progress downstream on the main stem. These are composed of a sensor in pipe casing and can be moved to different locations from year to year. Examples of supplemental gages include the La Platte river gage and the L-497 Main Outfall drainage gage.

US – Upstream

VBA – Visual Basic for Applications

WSE – Water Surface Elevation

1.0 Introduction

The purpose of this report is to document the socioeconomic impacts of the May 2009 spring pulse released from Gavins Point Dam and the socioeconomic impacts of natural spring rises on interior drainage on the Lower Missouri River from Gavins Point Dam to the mouth. Each year there is a potential for the release of two spring pulses from Gavins Point Dam. The March created spring pulse from Gavins Point Dam was not conducted in 2009 due to high downstream flows. The combination of downstream flows at Kansas City and the NWS forecast for rain in the lower Missouri River basin would have pushed the Missouri River above the flow limits. The May 2009 created spring pulse was released at noon on May 18. The peak of the May 2009 spring pulse from Gavins Point Dam was 6.1 kcfs for a total release of 23 kcfs.

Monitoring of the Lower Missouri River was completed prior to, during, and following the May 2009 spring pulse release. Monitoring objectives were to collect hydrologic data to evaluate if the May 2009 spring pulse created socioeconomic impacts to land adjacent to the Missouri River and to capture the effects of natural spring rises on the Lower Missouri River.

A total of 44 sites along the Missouri River were used. Nineteen of these sites were interior-drainage sites monitored to capture possible socioeconomic impacts from the spring pulse released from Gavins Point Dam and possible socioeconomic impacts due to natural spring rises. Data loggers installed at 19 sites recorded water surface elevations at interior drainage sites and along the main stem of the Missouri River in hourly increments from roughly March 1, 2009 through late September 2009. In addition, stage data from 25 automatic sites along the main stem of the Missouri River were also used to track the created spring pulse. Surveys of field elevations were completed in early 2009 to more accurately quantify possible socioeconomic impacts. The monitoring effort was developed and coordinated by the Hydrologic Engineering Branch of the U.S. Army Corps of Engineers (USACE), Omaha and Kansas City Districts. The U.S. Geographic Survey (USGS) assisted in data collection and equipment installation.

2.0 Background Information

The spring pulse released from Gavins Point Dam is the product of interagency collaboration between USACE and the Fish and Wildlife Service (FWS). Spring pulses were planned for release in March and May of 2009 if water storage within the main stem dams was sufficient and downstream flow limits were not violated. The purpose of the spring pulse releases is to mimic historic natural spring rises that occurred before the closure of the main stem dams to benefit the endangered pallid sturgeon. Historic natural spring rises were driven by snowmelt runoff from the plains and Rocky Mountains. Runoff from the plains typically produced a rise in March while runoff from the Rocky Mountains and spring rains typically produced a second rise in May and June.

3.0 2009 Analysis Improvements & Changes

Improvements in the analysis methodology and data collection for 2009 were the following.

§ Field and/or drainage-ditch berm elevations were surveyed in 2009 to provide a more objective measurement of flooding socioeconomic impacts. This new information was

then used along with the water surface elevations collected in 2008 to update the 2008 impact results.

§ A larger number and variety of drainage structures were monitored in 2009 in clumped locations to quantify socioeconomic impacts to lands protected by various drainage structures in the same general location.

§ Data collection platforms (DCPs) were installed at L-497 (RM 477.1) and Brunswick Terminal (RM 256.3) and the Spring Pulse study began funding the USACE Napoleon site (RM 328.7).

§ Lag time is considered in the interpolation of Missouri River flows at the sites. In the 2008 analysis, the magnitude of flow in the Missouri River was estimated through linear interpolation based on river mile, but the lag time between the sites was not considered. In 2009 lag time between the sites was considered because there were high peak flows with short durations and the original interpolation method produced lower flows at some DS gages in comparison with US gages. Consideration of lag time produced more realistic results.

§ Missouri River flows required to reach the sites' inlet and outlet inverts were estimated. These flows are called inlet- and outlet-threshold flows in this report.

§ Multiple points on the rising limbs of the hydrograph were used to estimate the impact, inlet, and outlet-flow thresholds. In 2008 a single point was taken and its value checked against other rises if possible. In 2009 an Excel macro was written in visual basic for applications (VBA) to find the elevations and flows to use in the calculations and take the average. Points chosen by the model were screened to make sure they were both on the rising limbs of the stage and flow data.

§ USACE rainfall gage data over main stem gages were used in place of the NWS experimental multi-sensor gage data where possible.

§ The accumulation of water in drainage ditches is not documented as an impact in 2009. Accumulation may impact crops by raising groundwater levels, but it is closely related with gate closures, which are considered in the impact evaluation.

§ Screens were added to the supplemental gage casing to reduce sedimentation problems.

§ A glossary was added to help clarify terms and acronyms used throughout the report.

4.0 Comparison of 2009 and 2008 Conditions

Figures 4.1 through 4.3 compare the flow patterns of the 2008 and 2009 monitoring periods at Omaha, NE; Kansas City, MO; and Waverly, MO; respectively. The 2008 record experienced a long duration large rise that began in late May and continued through mid-June or early July depending on the river location. In contrast, the 2009 record experienced several shorter duration rises scattered through the record.

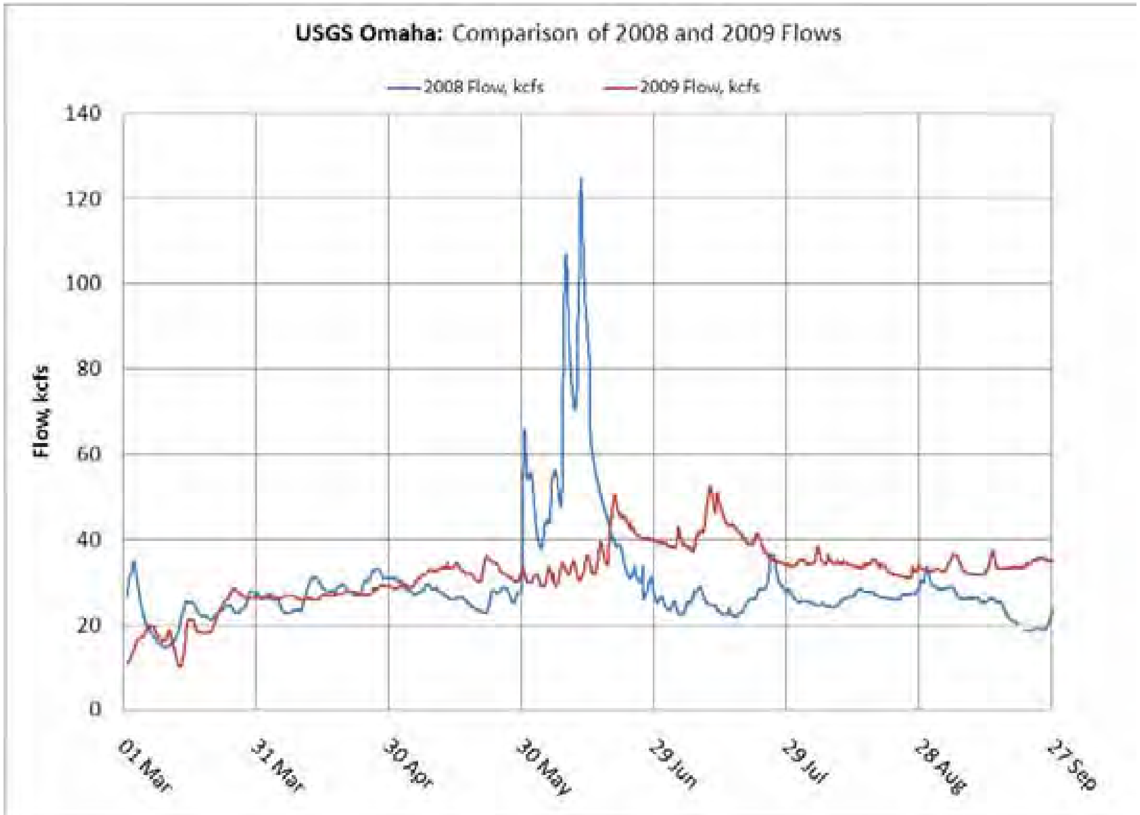

Figure 4.1 – USGS Omaha, 2008 and 2009

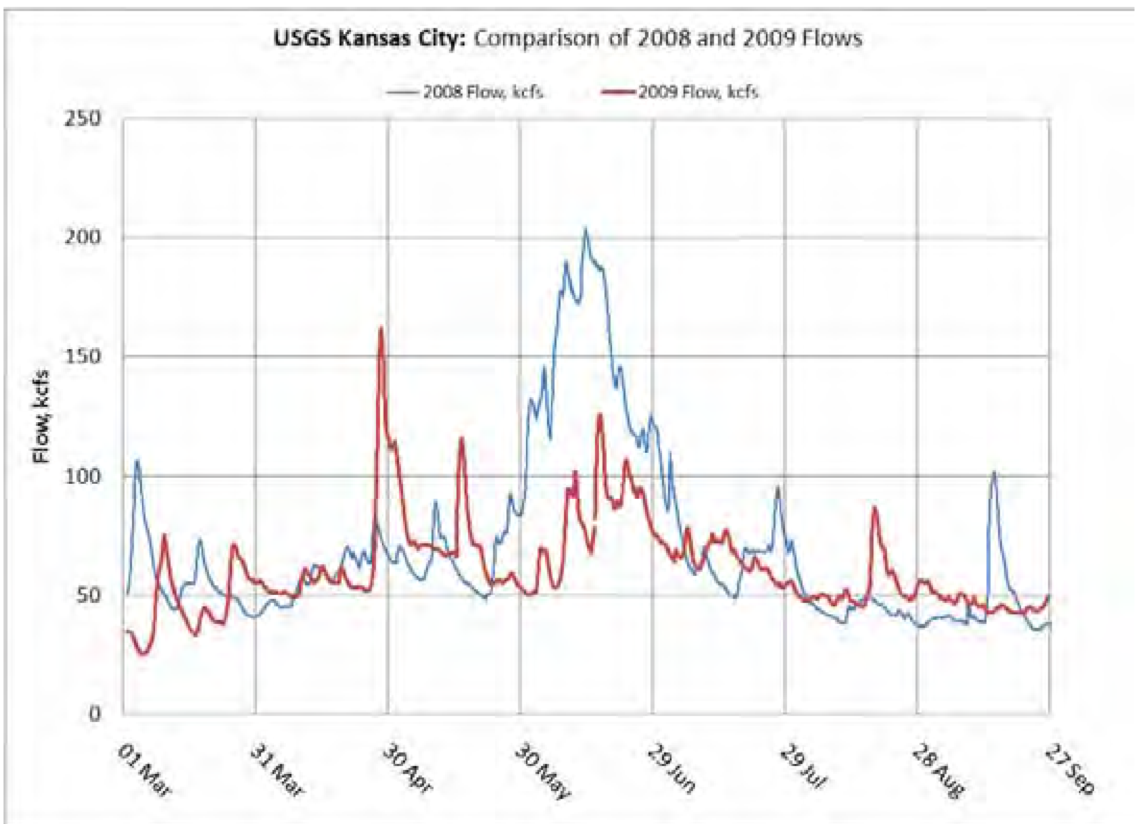

Figure 4.2 – USGS Kansas City, 2008 and 2009

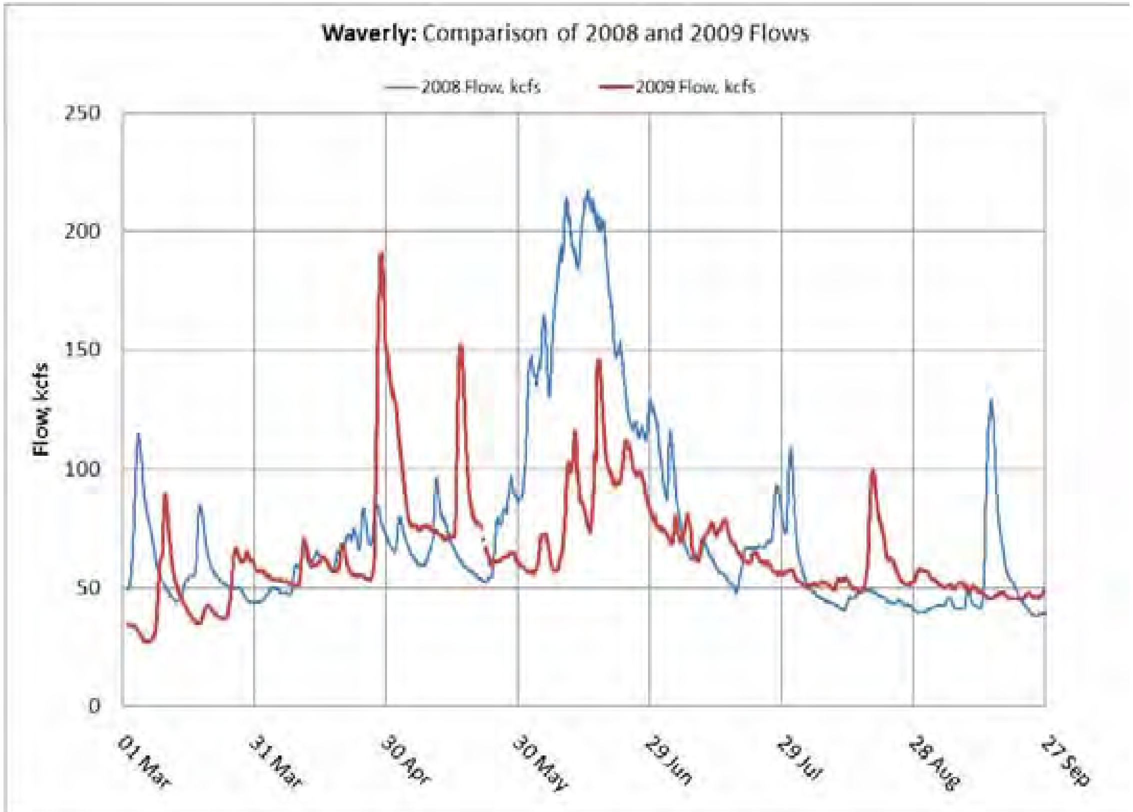

Figure 4.3 – USGS Waverly, 2008 and 2009

5.0 May 2009 Spring Pulse

Figure 5.1 shows the May 2009 spring pulse release from Gavins Point Dam. The 6.1-kcfs spring pulse release was added to a previously established 17-kcfs navigation level on May 18, 2009 at 12:00 p.m. The peak was held at a total 23 kcfs and then gradually decreased over 6 days. Six-hour duration peaking on a 3-day cycle was implemented before the release of the spring pulse to dissuade terns and plovers from nesting too low on sandbars.

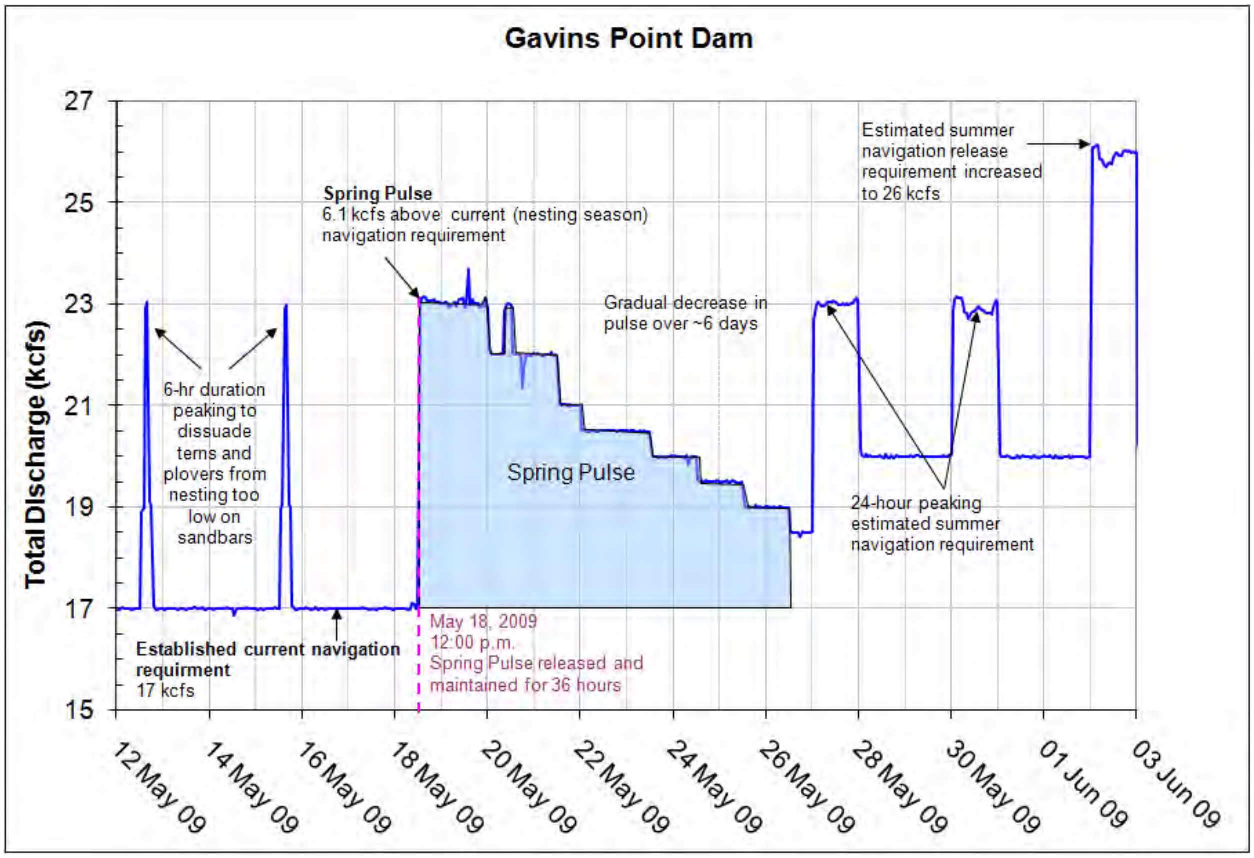

Figure 5.1 – May 2009 spring pulse release. The 6.1-kcfs May 2009 spring pulse was released from Gavins Point Dam at noon on May 18, 2009 after 6-hr duration peaking. The pulse was added to an already established current navigation level of 17 kcfs.

6.0 Rainfall Data

Rainfall data are shown for each site except Gavins Point Dam. These data are point rainfall amounts and not adjusted to basin areas. They are used as a qualitative reference to help determine rainfall influences on the stages recorded at each site. Precipitation from USACE main stem gages were used where available. Multi-sensor precipitation was used for supplemental sites and main stem sites without precipitation data for the study period. The multi-sensor precipitation data were processed from an ArcGIS shapefile from the National Weather Service and are experimental data.

7.0 Monitoring Sites and Major Tributaries

Table 7.1 lists the 19 interior drainage sites used to estimate possible impacts and if the site has a pump, flap gate, or manual gate.

Table 7.2 lists the 25 automatic gages used in the study and their characteristics including river mile, gage, data available for the time period of the study, datum, flood stage (if applicable), and travel time from Gavins Point Dam. Automatic gages have data collection platforms (DCPs) that allow satellite transmission of data. Five of these automatic gages (L-575 Structure No. 23, L-497 Main Outfall, L-408, Napoleon, and Brunswick Terminal) were installed with funding from the spring pulse project and will likely be temporary. Some automatic gages were installed at interior drainage sites, but most are located on the main stem of the Missouri River.

Figure 7.1 shows the location of all 44 sites used in this study. Twenty four sites are main stem gages on the Missouri River. These gages were monitored to track the created spring rise down the Missouri River. Figure 7.2 shows the 2008 monitoring sites for comparison. Note that the MO Valley LD No. 1 site monitored in 2008 is not the same as the MO Valley DLD site monitored in 2009. Figure 7.3 shows the major tributaries to the Missouri River. These include the Platte, Grand, Chariton, and Osage Rivers.

Table 7.3 lists the gage characteristics of the supplemental monitoring sites including the year they were installed and the gage type. Travel time at both navigation and bankfull flows are provided as both were referenced in this analysis. Supplemental gages are temporary, can be moved from year to year, do not have satellite capabilities, and are uninstalled before winter.

Table 7.1 – 2009 Interior-drainage monitoring sites

#	Site	RM	Gage Type	Pump	Flap Gate	Manual Gate
1	County Line Ditch	659	Ditch	N	N	N
2	California Bend	650.6	Levee	N	Y	N
3	McIntosh Ditch	637.1	Levee	N	Y	N
4	L-575 Structure No. 23	545.9	Levee	Y	Y	Y
5	L-536 Structure No. 8	521.5	Levee	Y	N	Y
6	Holt County LD No. 9	490.8	Levee	N	Y	N
7	R-500	480.2	Levee	Y	N	Y
8	L-497 Main Outfall	477.1	Levee	Y	N	Y
9	L-488	472.8	Levee	Y	N	Y
10	L-448/443	428.4	Levee	Y	N	Y
11	L-408 Main Outfall	391.9	Levee	N	Y	Y
12	MO Valley DLD	328.7	Levee	N	Y	Y
13	Dewitt DLD	255.3	Levee	N	Y	N
14	Miami LD No. 1	252.1	Levee	N	Y	N
15	Brunswick LD	250.3	Levee	Y	Y	N
16	L-246 Palmer Creek MD	241.8	Levee	N	Y	Y
16	L-246 Palmer Creek SD	241.8	Side Ditch	N	Y	N
17	L-246 Dalton Ditch MD	239.4	Levee	Y*	Y	Y
17	L-246 Dalton Ditch SD	239.4	Side Ditch	Y*	Y	N
18	Tebbetts East LD	124.8	Levee	N	Y	N
19	Howard Levee	124.4	Levee	N	Y	N

MD = main ditch through levee, SD = side ditch through side berm of main ditch
*Site has a movable pump

Table 7.2 – 2009 Automatic monitoring sites

#	Gage	River Mile (mi)	Data	Datum	Flood Stage (ft)	Travel Time (Days)	
						Nav. Flows	Bankfull Flows
1	Gavins Point Dam	811.1	Q, S, P	0	-	0.0	0.0
2	Yankton	805.8	Q, S, P	1139.7	32	0.1	0.1
3	Gayville	796	S	1100	55	0.3	0.2
4	Maskell	775.6	S	1100	30	0.6	0.4
5	Ponca	751	S	1080	24	1.1	0.7
6	Sioux City	732.3	Q, S, P	1057	36	1.4	0.9
7	Decatur	691	Q, S, P	1010	35	1.9	1.3
8	Blair	648.3	S, P	977.3	29	2.5	1.6
9	Omaha	615.9	Q, S, P	948.2	29	2.9	1.9
10	Plattsmouth	591.5	S	928.2	26	3.2	2.1
11	Nebraska City	562.6	Q, S, P	905.4	28	3.5	2.3
12	L-575 Structure No. 23*	545.9	S	-	-	3.7	2.5
13	Brownville	535.3	S	860	32	3.8	2.6
14	Rulo	498.1	Q, S	837.2	17	4.3	2.9
15	L-497 Main Outfall*	477.1	S	-	-	4.6	3.1
16	St. Joseph	448.2	Q, S	788.2	17	5.0	3.3
17	L-408 Main Outfall*	391.9	S	-	-	5.7	3.8
18	Kansas City	366.1	Q, S, P	706.4	32	6.0	4.0
19	Napoleon*	328.7	S	680.2	17	6.5	4.3
20	Waverly	293.4	Q, S	646	20	6.9	4.6
21	Brunswick Terminal*	256.3	S	-	-	7.4	4.9
22	Glasgow	226.3	Q, S, P	586.5	25	7.7	5.2
23	Boonville	197.1	Q, S	565.4	21	8.1	5.4
24	Jefferson City	143.9	S	520.2	23	8.7	5.8
25	Hermann	97.9	Q, S, P	481.6	21	9.3	6.2

Q=Flow, S=Stage, P=Precipitation
*Automatic gages installed for the spring pulse monitoring study

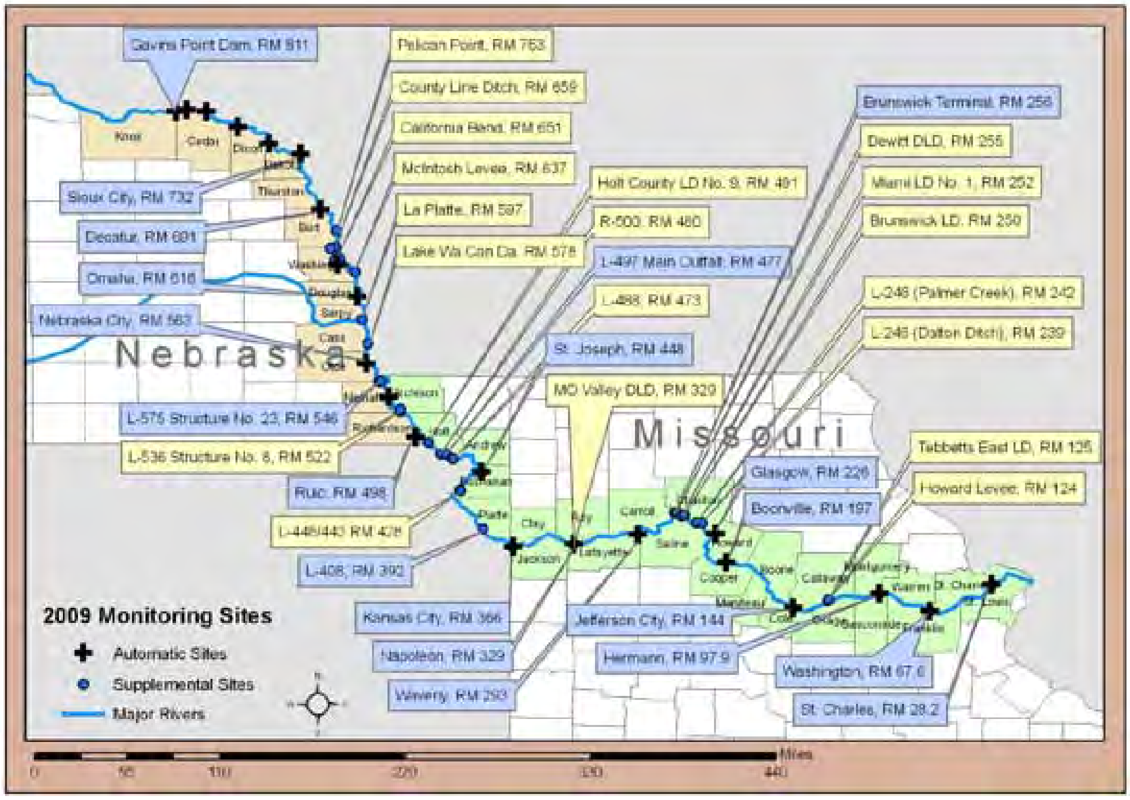

Figure 7.1 – 2009 monitoring sites. Blue callouts are automatic gages on either the main stem of the Missouri River or along drainage ditches. Yellow callouts are supplemental sites installed in 2009.

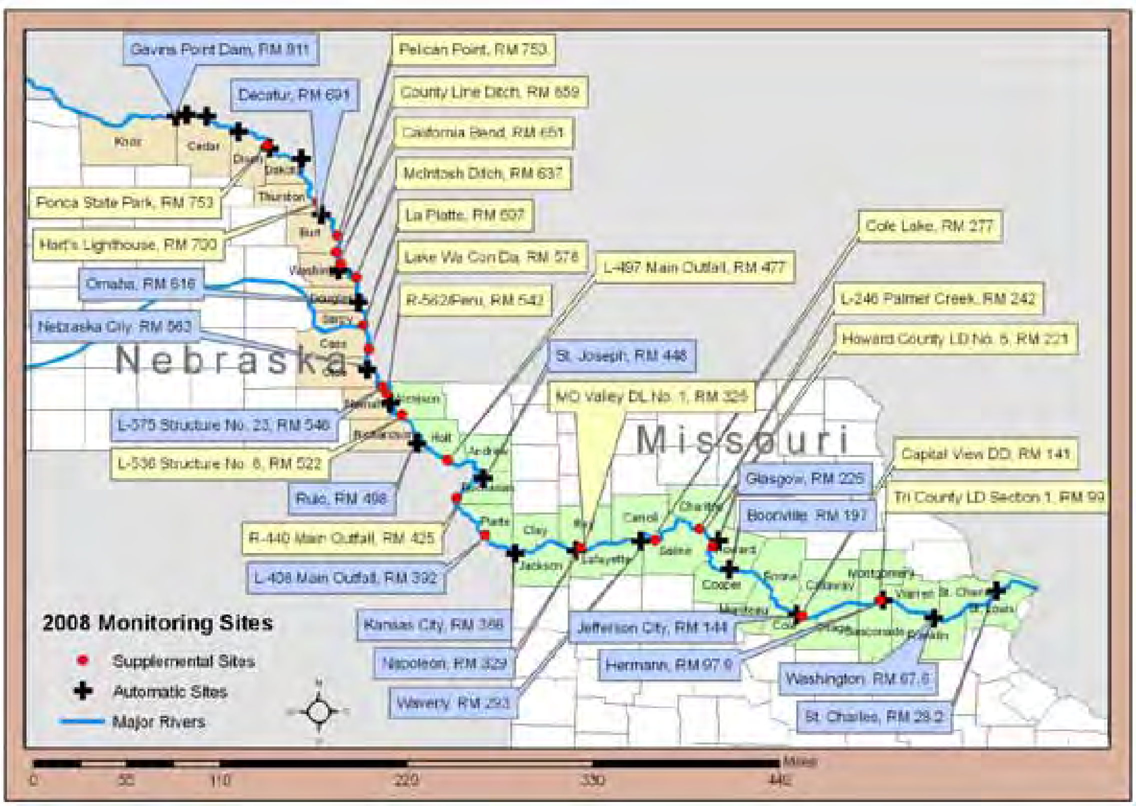

Figure 7.2 – 2008 monitoring sites. Blue callouts are automatic gages on either the main stem of the Missouri River or along drainage ditches. Yellow callouts are supplemental sites installed in 2008.

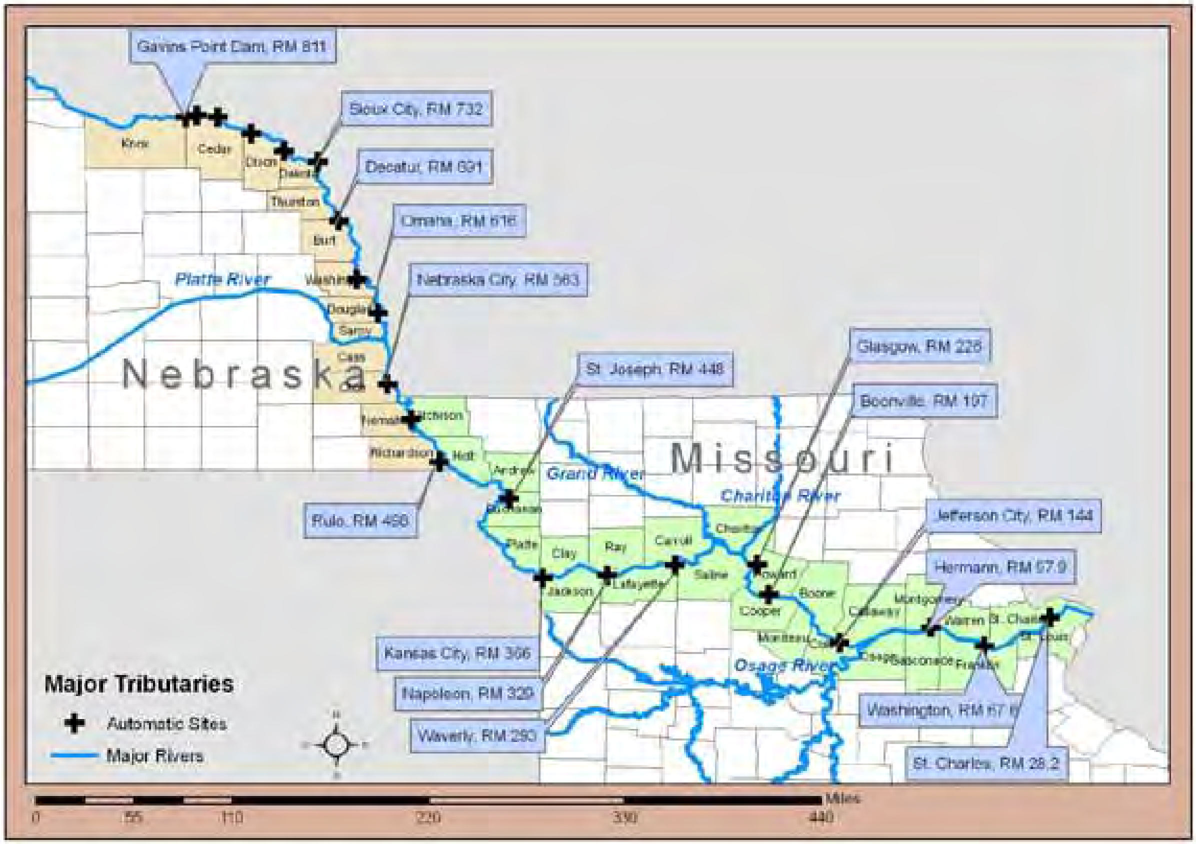

Figure 7.3 – Major tributaries. Major tributaries to the Missouri River include the Platte, Grand, Chariton, and Osage Rivers. Automatic main stem gages are shown for reference.

Table 7.3 – 2009 Supplemental monitoring gages

#	Site	Gage	River Mile (mi)	Installation Year	Travel Time (Days)*	
					Navigation Flows	Bankfull Flows
1	Pelican Point	River	672.7	2006	2.1	1.4
2	County Line Ditch	US	659	2006	2.3	1.6
2	County Line Ditch	DS	659	2006	2.3	1.6
3	California Bend	LS	650.6	2006	2.4	1.6
3	California Bend	RS	650.6	2006	2.4	1.6
4	McIntosh Levee	LS	637.1	2006	2.6	1.7
4	McIntosh Levee	RS	637.1	2006	2.6	1.7
5	La Platte	River	596.7	2006	3.1	2.0
6	Lake Wa Con Da	River	577.5	2006	3.3	2.2
7	L-536 Structure No. 8	LS	521.5	2006	4.0	2.7
7	L-536 Structure No. 8	RS	521.5	2006	4.0	2.7
8	Holt County LD No. 9	LS	490.8	2006	4.4	3.0
8	Holt County LD No. 9	RS	490.8	2006	4.4	3.0
9	R-500	LS	480.2	2009	4.6	3.0
10	L-497 Main Outfall	LS	477.1	2006	4.6	3.1
11	L-488	LS	472.8	2009	4.7	3.1
11	L-488	RS	472.8	2009	4.7	3.1
12	L-448/443	LS	428.2	2009	5.2	3.5
12	L-448/443	RS	428.2	2009	5.2	3.5
13	L-408 Main Outfall	LS	391.9	2008	5.7	3.8
14	MO Valley DLD	LS	328.7	2009	6.5	4.3
15	Dewitt DLD	LS	255.3	2009	7.4	4.9
15	Dewitt DLD	RS	255.3	2009	7.4	4.9
16	Miami LD No. 1	LS	252.1	2009	7.4	4.9
16	Miami LD No. 1	RS	252.1	2009	7.4	4.9
17	Brunswick LD	LS	250.3	2009	7.4	5.0
17	Brunswick LD	RS	250.3	2009	7.4	5.0
18	L-246 Palmer Creek	LS	241.8	2008	7.5	5.0
18	L-246 Palmer Creek	Side Ditch	241.8	2009	7.5	5.0
18	L-246 Palmer Creek	RS	241.8	2008	7.5	5.0
19	L-246 Dalton Ditch	LS	239.4	2009	7.6	5.0
19	L-246 Dalton Ditch	Side Ditch	239.4	2009	7.6	5.0
20	Tebbetts East LD	LS	124.8	2009	9.0	6.0
21	Howard Levee	LS	124.4	2009	9.0	6.0
21	Howard Levee	RS	124.4	2009	9.0	6.0

*Referenced or interpolated from *U.S. Army Corps of Engineers* (2006)

8.0 Estimation of MR Flows at Supplemental Gages

Supplemental gages record pressures, which can be converted to stages, and not flows. Flows in the Missouri River at each supplemental gage site were estimated through three general processes: 1) interpolation from flow records at USGS gages along the Missouri River lagged to the site, 2) lagging an upstream or downstream USGS gage record to the site, and 3) lagging major gauged tributary flow records and adding them to USGS gage flow records along the main stem of the Missouri River. Major tributaries considered include the Platte, Grand, Chariton, and Osage Rivers. Flow interpolation was based on the river miles of the supplemental site and the river miles of the USGS gages upstream and downstream of the site. Table 8.1 summarizes how flows were estimated at each site.

Table 8.1 – Methods used in flow estimation at each site

Site	RM	Method	USGS Gage Data Used	Description
Pelican Point	672.7	Interpolation	Decatur & Omaha	Data lagged to site based on peaks & flows interpolated from lagged records
County Line	659	Interpolation	Decatur & Omaha	Data lagged to site based on peaks & flows interpolated from lagged records
California	650.6	Interpolation	Decatur & Omaha	Data lagged to site based on peaks & flows interpolated from lagged records
McIntosh	637.1	Interpolation	Decatur & Omaha	Data lagged to site based on peaks & flows interpolated from lagged records
La Platte	596.7	Lag	Omaha	Omaha flows lagged to site
Lake Wa Con Da	577.5	Lag	Nebraska City	Nebraska City flows lagged to site
L-575 Structure No. 23	545.9	Interpolation	Nebraska City	Nebraska City flows lagged to site
L-536 Structure No. 8	521.5	Interpolation	Nebraska City & Rulo	Data lagged to site based on peaks & flows interpolated from lagged records
Holt County LD No. 9	490.8	Interpolation	Rulo & St. Joseph	Data lagged to site based on peaks & flows interpolated from lagged records
R-500	480.2	Interpolation	Rulo & St. Joseph	Data lagged to site based on peaks & flows interpolated from lagged records
L-497 Main Outfall	477.1	Interpolation	Rulo & St. Joseph	Data lagged to site based on peaks & flows interpolated from lagged records
L-488	472.8	Interpolation	Rulo & St. Joseph	Data lagged to site based on peaks & flows interpolated from lagged records
L-448/443	428.4	Interpolation	St. Joseph & Kansas City	Data lagged to site based on peaks & flows interpolated from lagged records
L-408 Main Outfall	391.9	Interpolation	St. Joseph & Kansas City	Data lagged to site based on peaks & flows interpolated from lagged records
MO Valley DLD	328.7	Interpolation	Kansas City & Waverly	Data lagged to site based on peaks & flows interpolated from lagged records
Brunswick Terminal	256.3	Lag	Waverly	Waverly lagged to site based on peaks
Dewitt DLD	255.3	Lag	Waverly	Waverly lagged to site based on peaks
Miami LD No. 1	252.1	Lag	Waverly	Waverly lagged to site based on peaks
Brunswick LD	250.3	Lag	Waverly	Waverly lagged to site based on peaks
L-246 Palmer Creek MD	241.8	Trib Added	Sumner & Waverly	Grand added to Waverly and lagged to site
L-246 Dalton Ditch MD	239.4	Trib Added	Sumner & Waverly	Grand added to Waverly and lagged to site
Tebbetts East	124.8	Trib Added	St. Thomas & Boonville	Osage added to Boonville and lagged to site
Howard Levee	124.4	Trib Added	St. Thomas & Boonville	Osage added to Boonville and lagged to site

9.0 Spring Pulse Attenuation

9.1 Attenuation in Terms of Flow

Figure 9.1.1 shows automatic gages with flow data. Data from these gages were used to estimate the attenuation rate of the spring pulse release. Figures 9.2 through 9.9 show the flow data collected at each of these gages from May 12 through June 2, 2009. Precipitation at each site was referenced from the National Weather Service's multi-sensor (radar and rain gage) gridded rainfall. The created spring rise was identified at each site through the navigation travel time from Gavins Point Dam (labeled "SP Arrival" on graphs). The rise was then quantified by subtracting the peak flow from the base navigation flow.

Figures 9.1.2 through 9.1.9 show the estimation of the spring rise created by the spring pulse released from Gavins Point Dam. Table 9.1.1 summarizes these rises and shows the estimated attenuation rate of the spring pulse. Based on the analysis of the observed data presented in Figures 9.1.2 through 9.1.9, the 6.4-kcfs spring rise at USGS Sioux City attenuated in peak flow by about 77% by the time it reached Kansas City, MO in 2009.

Table 9.1.1 and Figure 9.1.10 show the trend line results of the observed May 2009 data. Unlike the March 2008 analysis, the May 2009 analysis does not include the spring rise at Gavins Point Dam (RM 811.1) but estimates the rate of attenuation beginning with the spring rise at USGS Sioux City (RM 732.3) where the Missouri River becomes channelized. This was changed because the May 2009 spring rise increased by 0.3 kcfs between Gavins Point Dam and USGS Sioux City. The line of best fit has a slope of 0.013 kcfs/RM, which indicates the 6.4-kcfs May pulse at Sioux City attenuated at approximately 1.3 kcfs for every 100 river miles in 2009.

Figure 9.1.11 and Table 9.1.2 show the observed March 2008 created spring rises by their river miles. The line of best fit has a slope of 0.0106 kcfs/RM, which indicates the 4.5-kcfs March spring pulse peak attenuated at approximately 1.1 kcfs for every 100 river miles in 2008.

Equation 9.1.1 is used in Section 10 to estimate the peak flow (Q_{SR}) of the May 2009 spring rise at each site by river mile (RM). Equation 9.1.2 is used in Section 10 to estimate the peak flow of the March 2008 created spring rise (Q_{SR}) by river mile along the Missouri River. This equation was determined by plotting the observed spring rises in 2008 by their river miles and fitting a line of best fit to the data (see the 2008 monitoring report for details). This equation is used in Section 10 to estimate the 2008 spring pulse peak flow at each site.

$$Q_{SR} = 0.0134 \times RM - 3.3553 \qquad \text{Equation 9.1.1}$$

$$Q_{SR} = 0.0106 \times RM - 3.9804 \qquad \text{Equation 9.1.2}$$

Tables 9.1.4 and 9.1.5 show observed and estimated spring pulse peak flows by site. Both the May 2009 and March 2008 results are provided. The calculated spring pulse peak flows were determined by river mile using Equations 9.1.1 and 9.1.2. Based on the attenuation equations, the May 2009 spring pulse peak fully attenuated around RM 252 about 40 miles downstream of the USGS Waverly gage, and the March 2008 spring pulse peak fully attenuated around RM 370 near the USGS Kansas City gage.

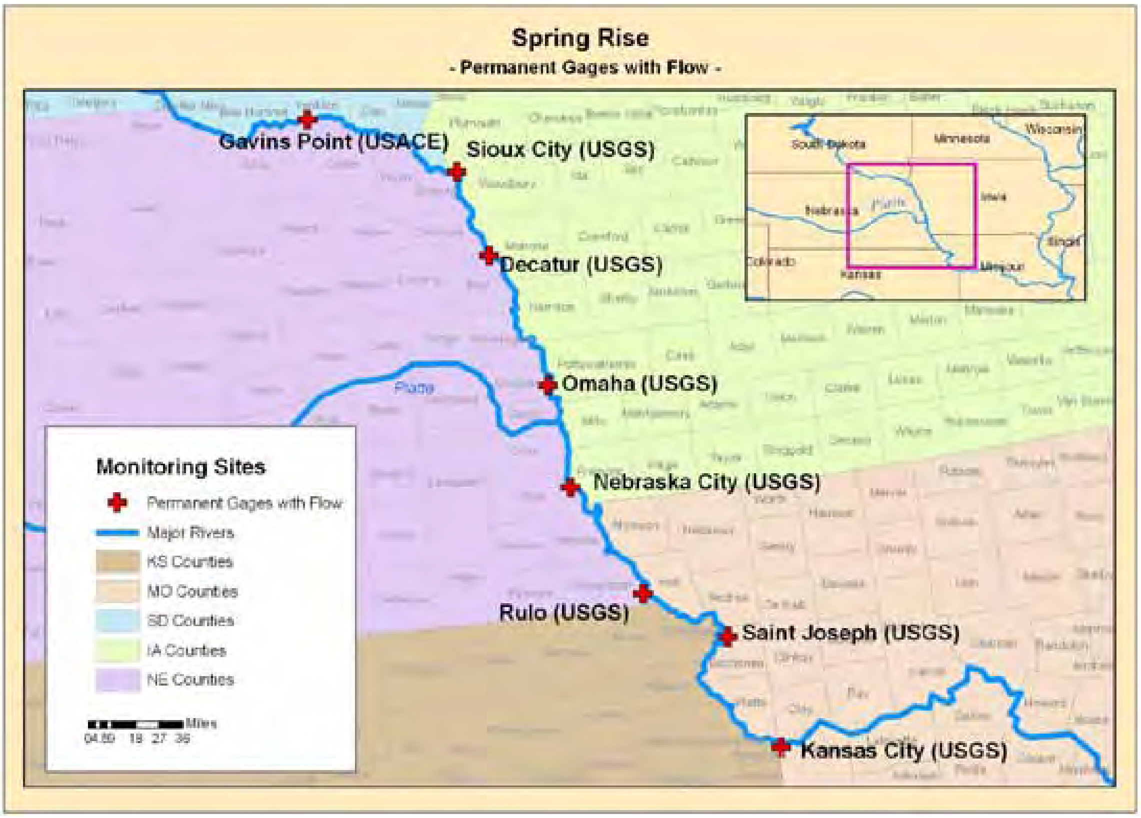

Figure 9.1.1 – Automatic gages with flow data

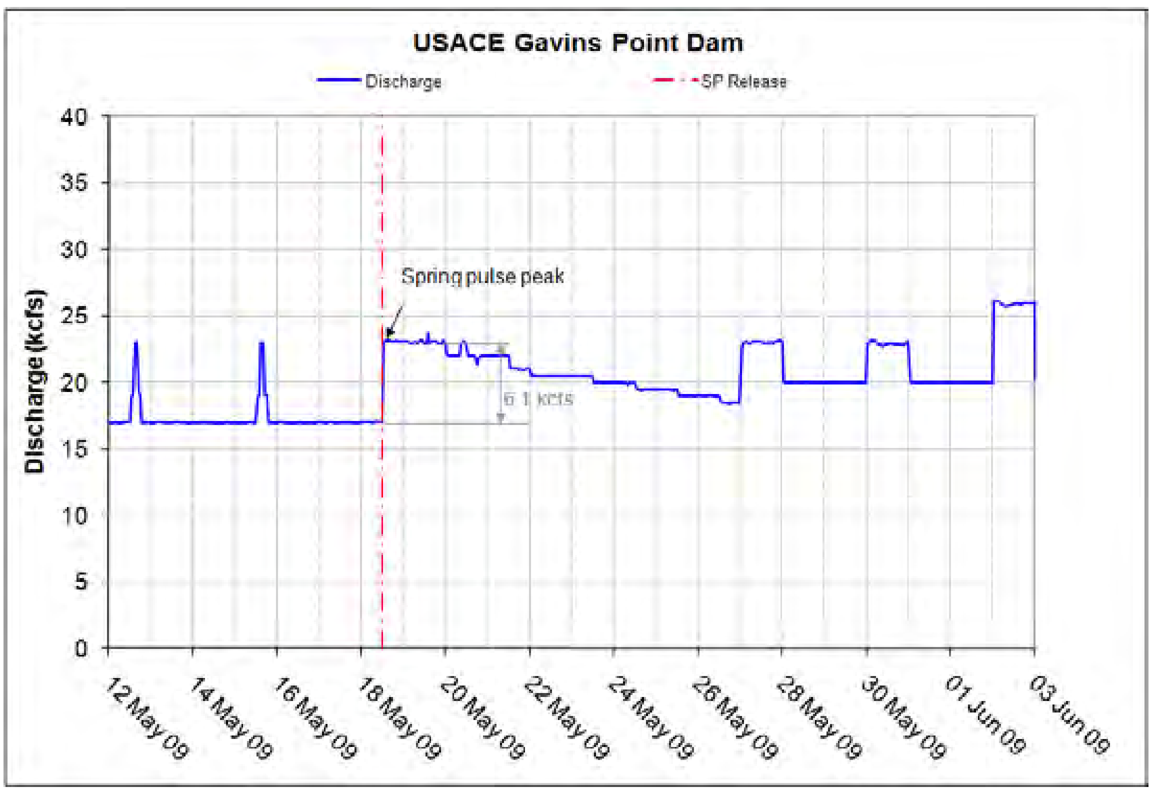

Figure 9.1.2 – Spring pulse at Gavins Point Dam (RM 811.1)

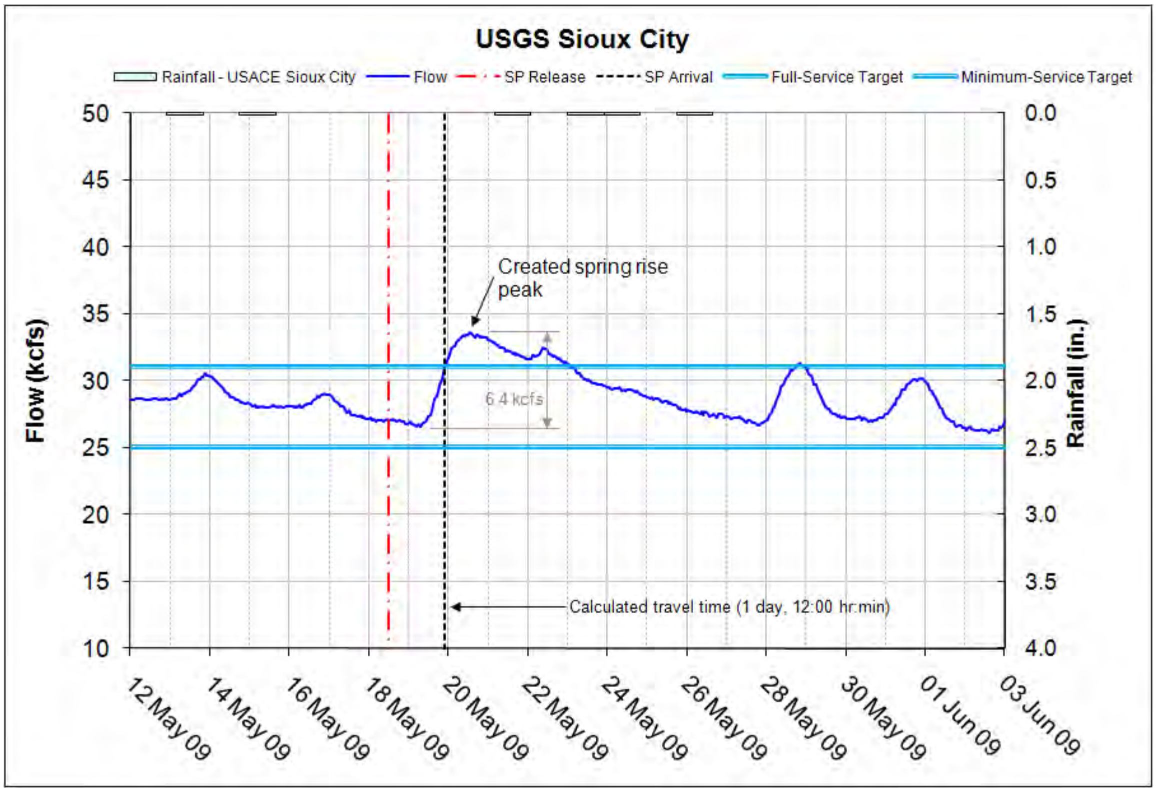

Figure 9.1.3 – Spring rise at USGS Sioux City (RM 732.3)

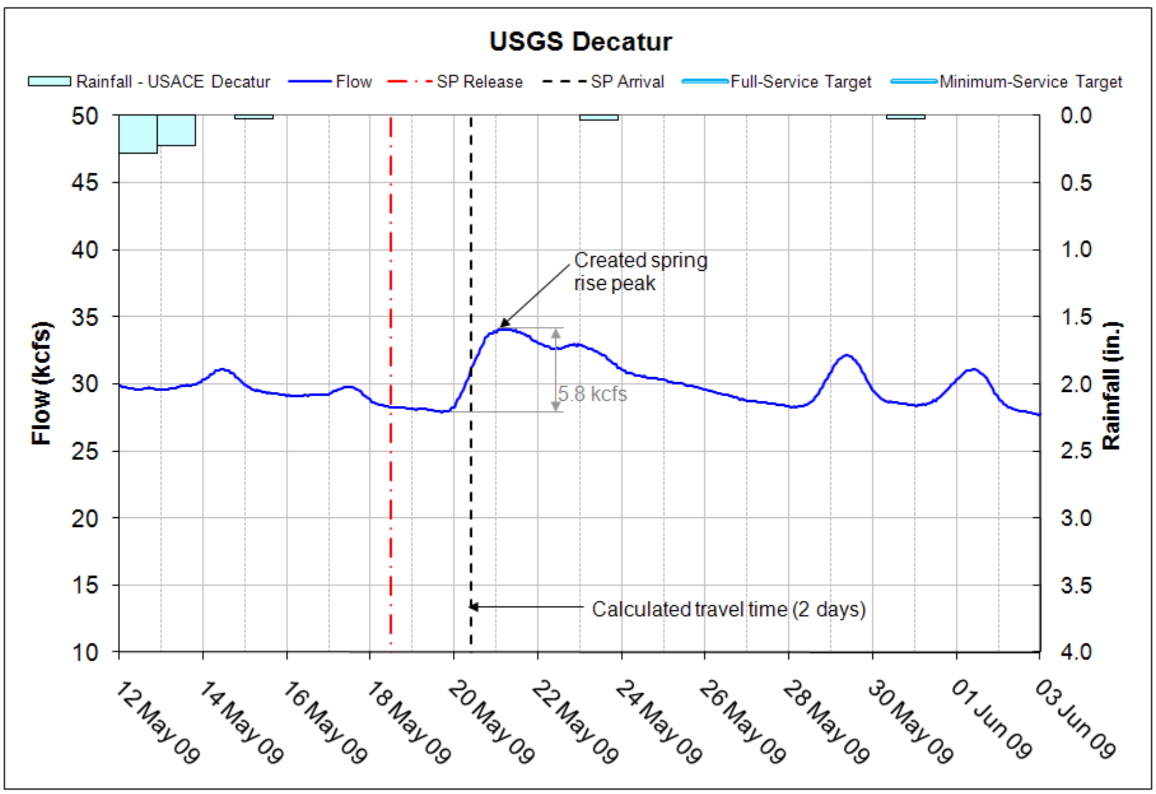

Figure 9.1.4 – Spring rise at USGS Decatur (RM 691)

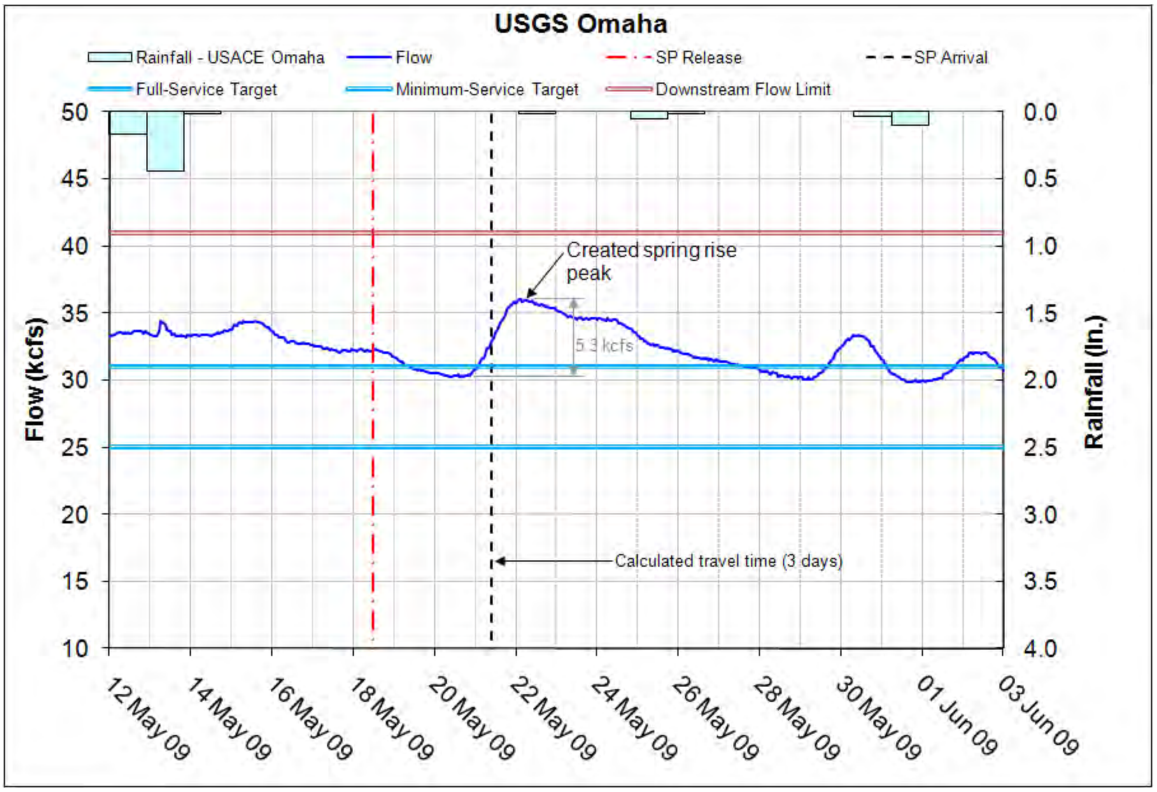

Figure 9.1.5 – Spring rise at USGS Omaha (RM 615.9)

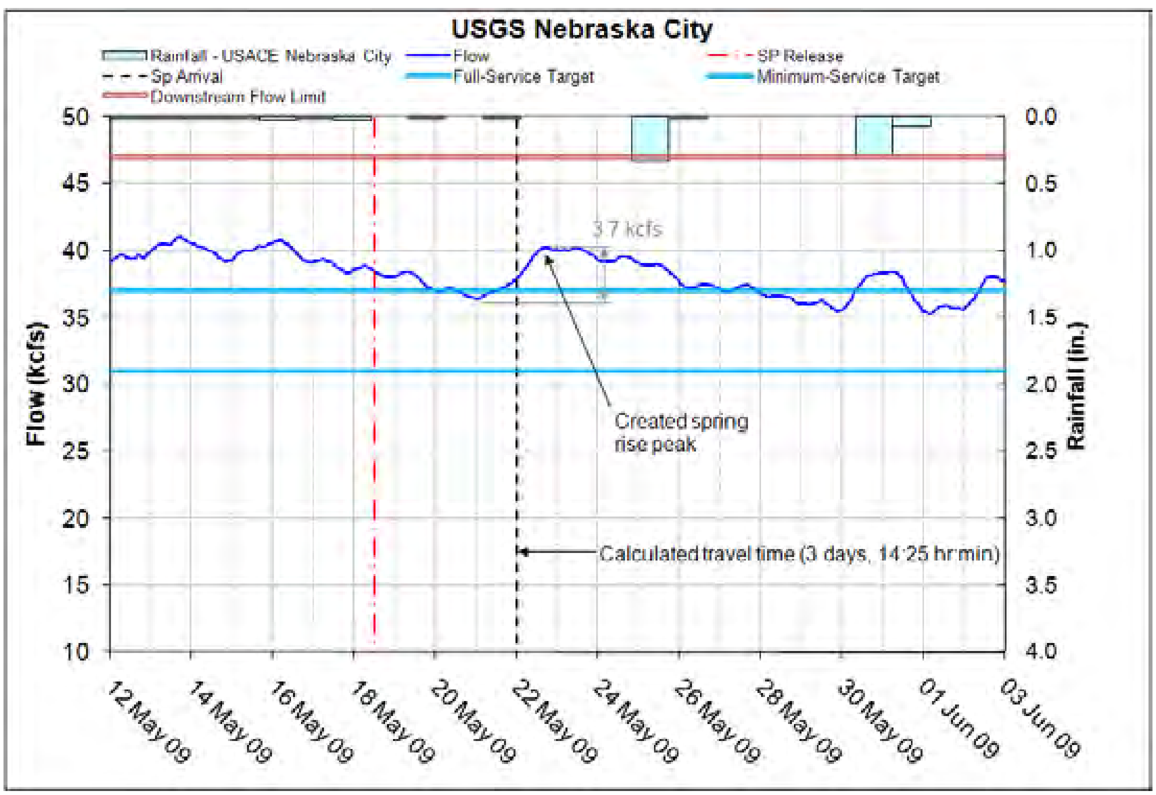

Figure 9.1.6 – Spring rise at USGS Nebraska City (RM 562.6)

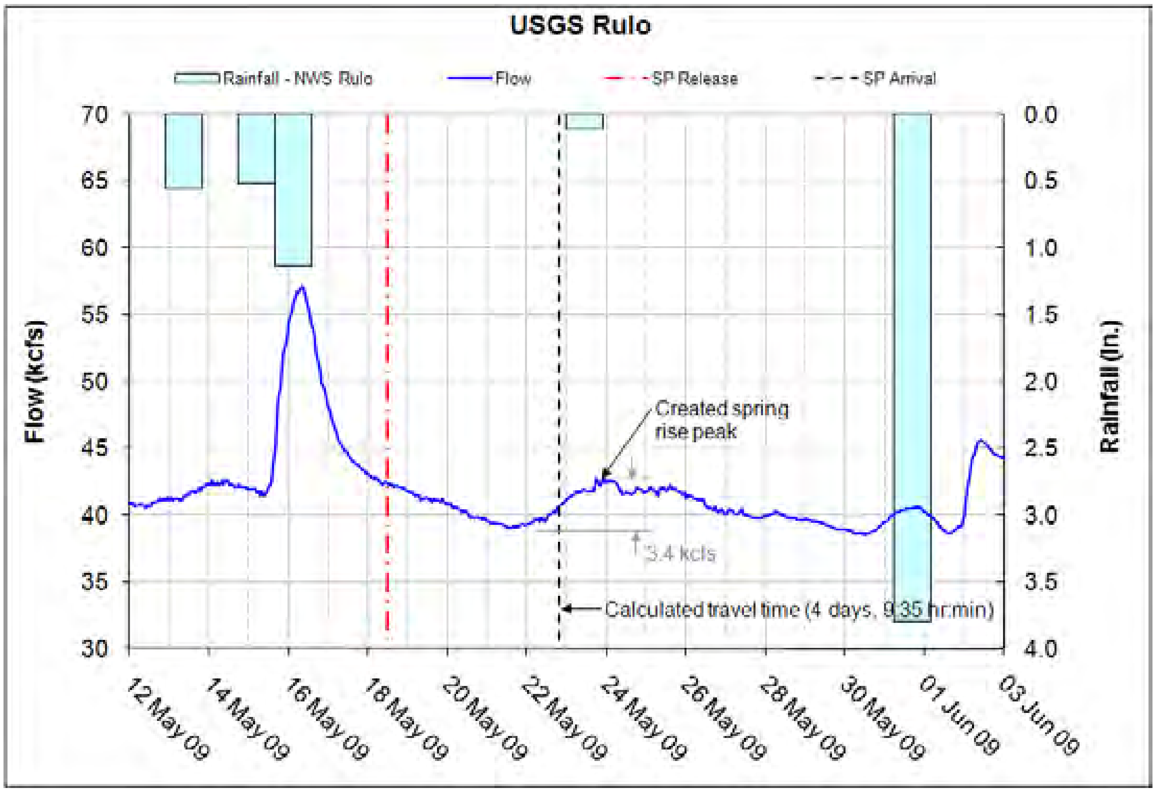

Figure 9.1.7 – Spring rise at USGS Rulo (RM 498.1)

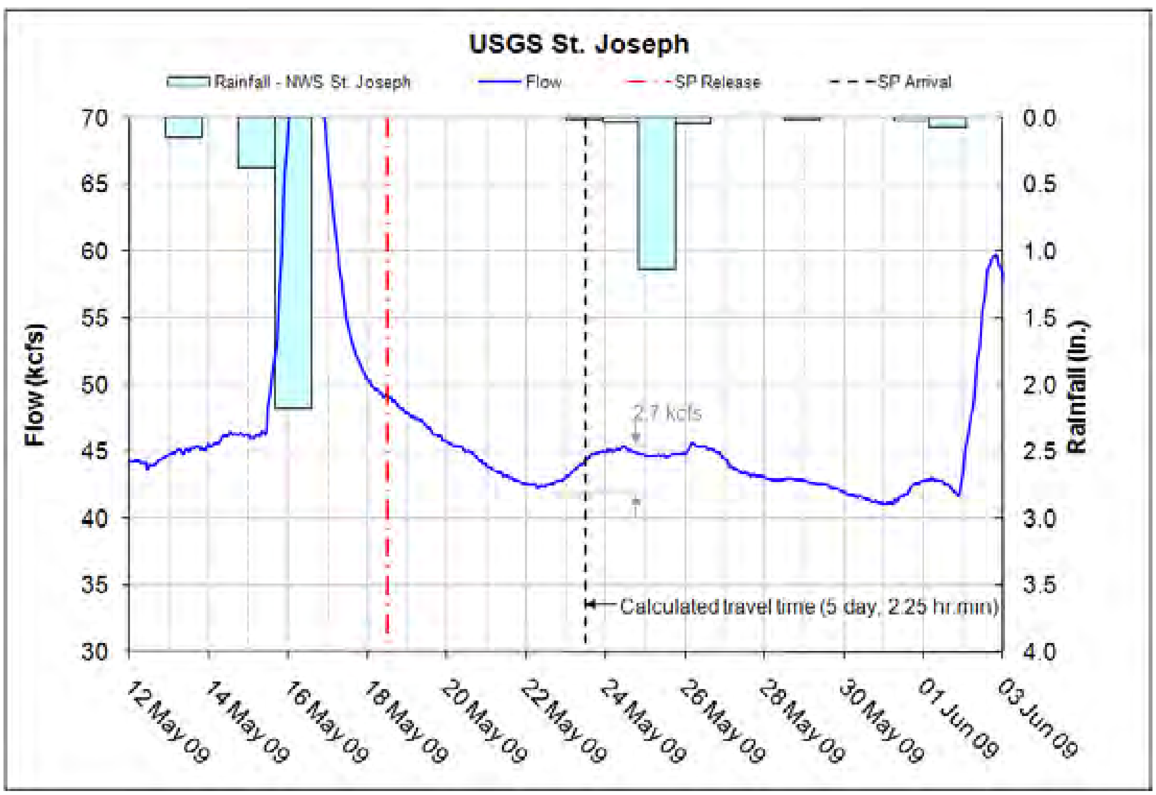

Figure 9.1.8 – Spring rise at USGS St. Joseph (RM 448.2)

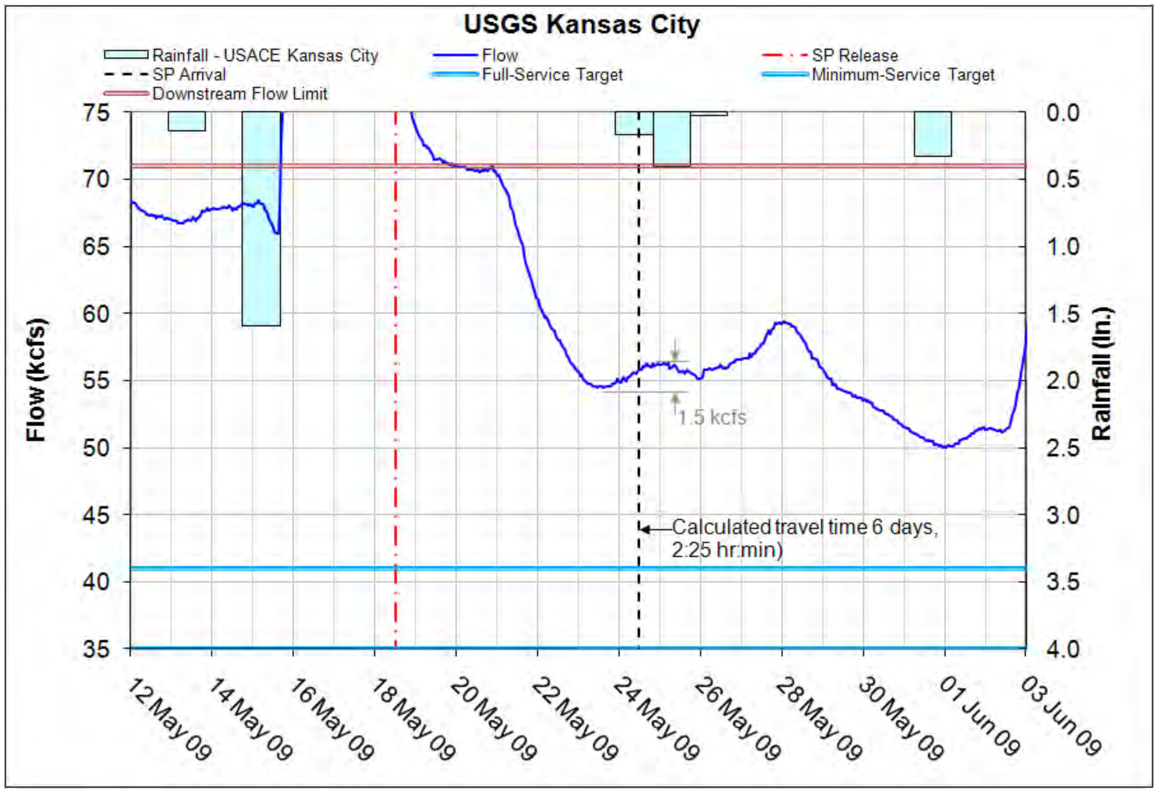

Figure 9.1.9 – Spring rise at USGS Kansas City (RM 366.1)

Table 9.1.1 – Observed spring-pulse attenuation, May 2009

Station	River Mile (mi)	Spring Rise Peak Flow (kcfs)	Attenuation
USACE Gavins Point Dam	811.1	6.1	-
USGS Sioux City	732.3	6.4	0%
USGS Decatur	691	5.8	9%
USGS Omaha	615.9	5.3	18%
USGS Nebraska City	562.6	3.7	42%
USGS Rulo	498.1	3.4	47%
USGS Saint Joseph	448.2	2.7	58%
USGS Kansas City	366.1	1.5	77%

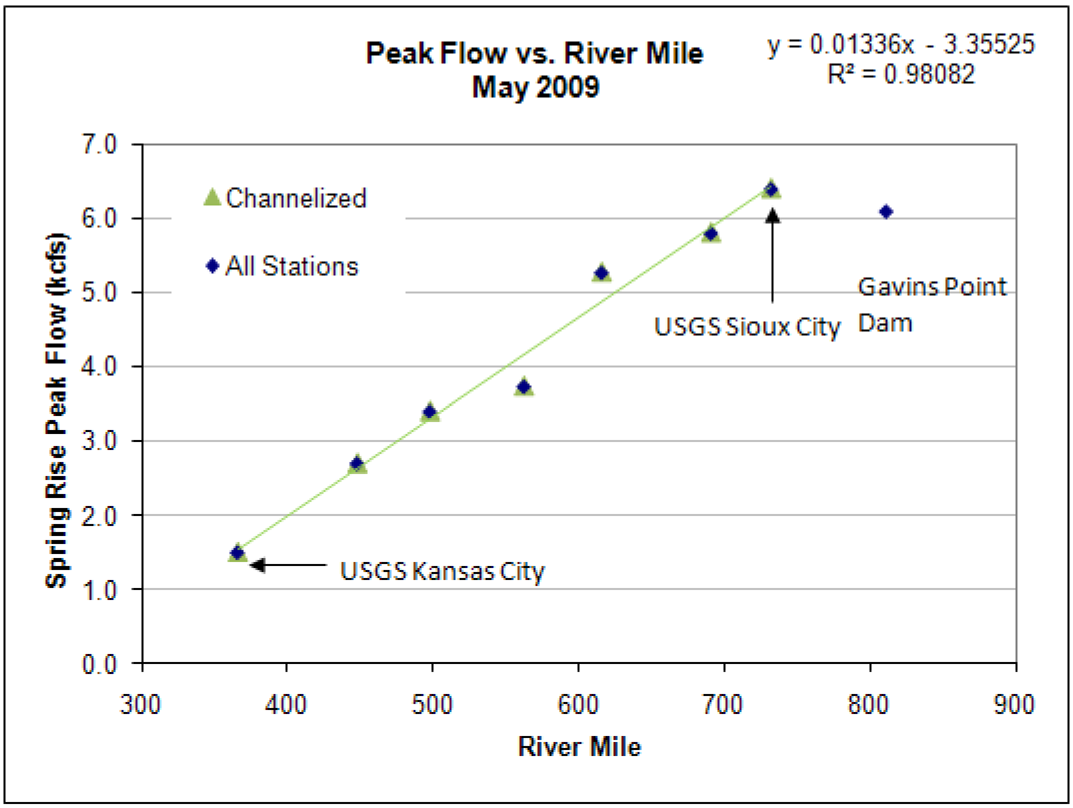

Figure 9.1.10 – Line of best fit for spring pulse attenuation, May 2009

Table 9.1.2 – Observed spring pulse attenuation, March 2008

Station	River Mile (mi)	Observed	
		Spring Rise Peak Flow (kcfs)	Attenuation
USACE Gavins Point Dam	811.1	4.5	0%
USGS Sioux City	732.3	4.1	9%
USGS Decatur	691	3.1	30%
USGS Omaha	615.9	3.0	33%
USGS Nebraska City	562.6	1.6	64%
USGS Rulo	498.1	1.4	69%
USGS Saint Joseph	448.2	n.a.	n.a.
USGS Kansas City	366.1	n.a.	n.a.

n.a. means the spring rise could not be objectively identified due to other affects

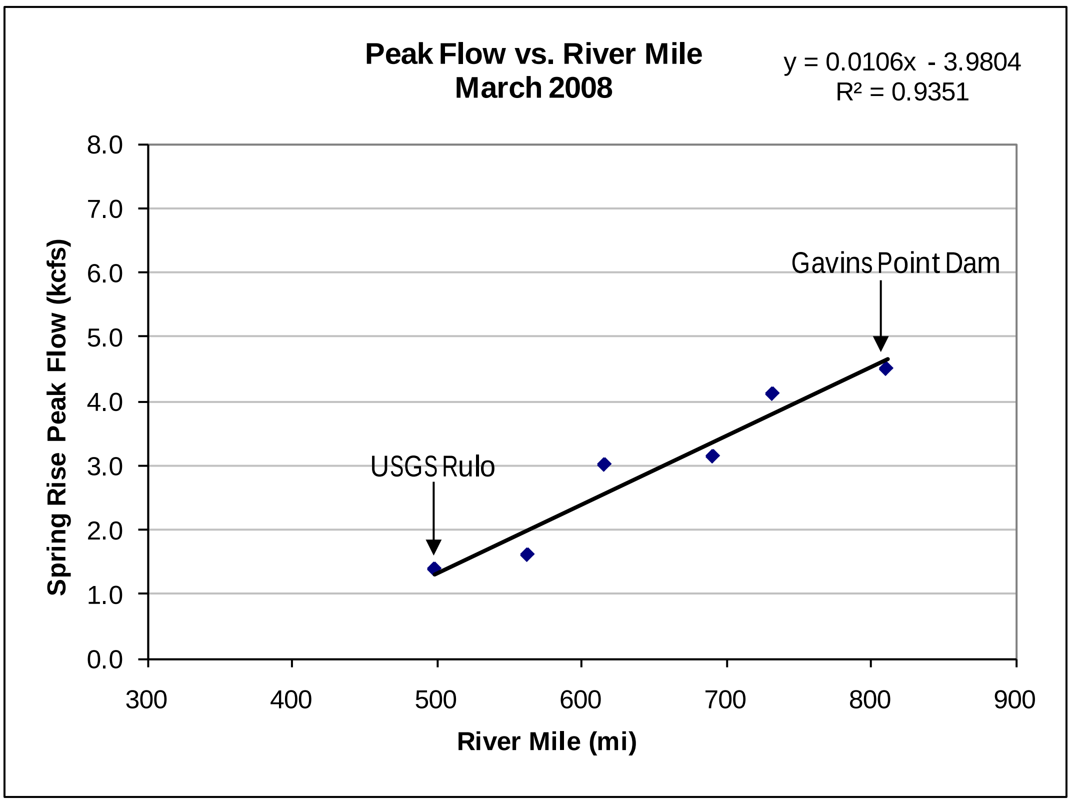

Figure 9.1.11 – Line of best fit for spring pulse attenuation, March 2008

Table 9.1.3 – Comparison of observed flow attenuation, March 2008 & May 2009

Station	River Mile (mi)	Spring Rise (kcfs)		Attenuation	
		Mar-08	May-09	Mar-08	May-09
USACE Gavins Point Dam	811.1	4.5	6.1	0%	-*
USGS Sioux City	732.3	4.1	6.4	9%	0%
USGS Decatur	691	3.1	5.8	30%	8%
USGS Omaha	615.9	3	5.3	33%	22%
USGS Nebraska City	562.6	1.6	3.7	64%	32%
USGS Rulo	498.1	1.4	3.4	69%	44%
USGS Saint Joseph	448.2	~0.8	2.7	~83%	53%
USGS Kansas City	366.1	~0	1.5	~100%	69%
Overall Attenuation Rate (kcfs/RM)				**0.011**	**0.013**
Overall Attenuation Rate (kcfs/100RM)				**1.1**	**1.3**

*Spring Pulse attenuation estimated from Sioux City, IA because flows observed to increase between Gavins Point Dam and Sioux City

~ means the spring rise could not be separated from other flows so the value was calculated from the attenuation equations presented in this section

Table 9.1.4 – Observed and estimated spring pulse peak flows (May 2009)

Site	RM (mi)	May 2009 Spring Pulse	
		Observed SP Q, kcfs	Calculated SP Q, kcfs
Gavins Point Dam	811.1	6.1	-
Yankton	805.8	-	-
Gayville	796	-	-
Maskell	775.6	-	-
Ponca	751	-	-
Sioux City	732.3	6.4	6.4
Decatur	691	5.8	5.9
Pelican Point	672.7	-	5.6
County Line Ditch	659	-	5.4
California Bend	650.6	-	5.3
Blair	648.3	-	5.3
McIntosh Ditch	637.1	-	5.2
Omaha	615.9	5.3	4.9
La Platte	596.7	-	4.6
Plattsmouth	591.5	-	4.5
Lake Wa Con Da	577.5	-	4.4
Nebraska City	562.6	3.7	4.2
L-575 Str No. 23	545.9	-	3.9
Brownville	535.3	-	3.8
L-536 Str No. 8	521.5	-	3.6
Rulo	498.1	3.4	3.3
Holt County	490.8	-	3.2
R-500	480.2	-	3.1
L-497	477.1	-	3.0
L-488	472.8	-	3.0
St. Joseph	448.2	2.7	2.6
L-448/443	428.2	-	2.4
L-408	391.9	-	1.9
Kansas City	366.1	1.2	1.5
Napoleon	328.7	-	1.0
MO Valley DLD	328.7	-	1.0
Waverly	293.4	-	0.6
Brunswick Terminal	256.3	-	0.1
Dewitt DLD	255.3	-	0.1
Miami LD No. 1	252.1	-	0
Brunswick LD	250.3	-	0
L-246 Palmer Creek	241.8	-	0
L-246 Dalton Ditch	239.4	-	0
Glasgow	226.3	-	0
Boonville	197.1	-	0
Jefferson City	143.9	-	0
Tebbetts East LD	124.8	-	0
Mokane Levee	124.4	-	0
Hermann	97.9	-	0

Table 9.1.5 – Observed and estimated spring pulse peak flows (March 2008)

Site	RM (mi)	March 2008 Spring Pulse	
		Observed SP Q, kcfs	Calculated SP Q, kcfs
USACE Gavins Point Dam	811.1	4.5	4.6
USGS Yankton	805.8	-	4.6
USACE Gayville	796	-	4.5
USGS Maskell	775.6	-	4.2
Ponca State Park	753.4	-	4.0
USACE Ponca	751	-	4.0
USGS Sioux City	732.3	4.1	3.8
Harts Lighthouse Marina	699.5	-	3.4
USGS Decatur	691	3.1	3.3
Pelican Point	672.7	-	3.2
County Line Ditch	659	-	3.0
California Bend	650.6	-	2.9
USACE Blair	648.3	-	2.9
McIntosh Ditch	637.1	-	2.8
USGS Omaha	615.9	3	2.5
La Platte	596.7	-	2.3
USACE Plattsmouth	591.5	-	2.3
Lake Wa Con Da	577.5	-	2.1
USGS Nebraska City	562.6	1.6	2.0
L-575 Structure No. 23	545.9	-	1.8
R-562/Peru	542.1	-	1.8
USACE Brownville	535.3	-	1.7
L-536 Structure No. 8	521.5	-	1.5
USGS Rulo	498.1	1.4	1.3
L-497 Main Outfall	477.1	-	1.1
L-488	472.8	-	1.0
USGS St. Joseph	448.2	-	0.8
R-440 Main Outfall	424.9	-	0.5
L-408 Main Outfall	391.9	-	0.2
USGS Kansas City	366.1	-	0
USACE Napoleon	328.7	-	0
MO Valley LDD No. 1	326.2	-	0
USACE Waverly	293.4	-	0
Cole Lake DD No. 2	277.1	-	0
L-246 Palmer Creek	241.8	-	0
USACE Glasgow	226.3	-	0
Howard County LD No. 6	221.2	-	0
USGS Boonville	197.1	-	0
USGS Jefferson City	143.9	-	0
Capital View DD	141.4	-	0
Tri-County LD Section No. 1	99.6	-	0
USGS Hermann	97.9	-	0
USGS St. Charles	28.2	-	0

9.2 Attenuation in Terms of Stage

Attenuation in terms of stage was also considered. Table 9.2.1 shows the observed spring rise at USACE and USGS main-stem gages for the channelized portion of the Missouri River from USGS Sioux City (RM 732.3) to USGS St. Charles (RM 28.2). The May 2009 results are shown on a site-by-site basis in Section 10. The March 2008 results are from the *Missouri River Recovery Program 2008 Spring Pulse and Rises Drainage Monitoring and Evaluation* report. The May 2006 results are from the *Missouri River Mitigation Project 2006 Spring Pulse Interior Drainage and Groundwater Modeling After-Action Report*.

March 2008 and May 2009 considered precipitation and the influence of upstream flows. The May 2006 data did not consider if the spring rises documented included the effects of precipitation and upstream flow. This is probably why the spring rise increased at USGS Hermann and USGS St. Charles in 2006 while it decreased in March 2008 and May 2009. The May 2006 data at USGS Hermann and St. Charles are reported in Table 9.2.1 but are not considered in the estimate of attenuation rates.

Figure 9.2.1 shows the change in stage at the USGS and USACE main stem gages from USGS Sioux City (RM 732.3) to USGS St. Charles (RM 28.2) for May 2006, March 2008, and May 2009. The scatter in the stage data is much larger than in the flow data. This scatter is reflected in the correlation coefficient (R^2) of the lines of best fit. Therefore, the estimated attenuation rate in terms of stage is not as strong as the attenuation rate in terms of flow.

In general, the May 2009 spring pulse attenuated at a rate of 0.0035 ft/RM (0.4 ft / 100 RM), the March 2008 spring pulse attenuated at a rate of 0.0043 ft/RM (0.4 ft / 100 RM), and the May 2006 spring pulse attenuated at a rate of 0.0033 ft/RM (0.3 ft / 100 RM).

Table 9.2.1 – Observed CSR in channelized Missouri River; May 2009, March 2008, and May 2006

		Observed Created Spring Rise, ft		
Site	**RM**	**May-09**	**Mar-08**	**May-06**
USGS Sioux City	732.3	1.8	1.5	2.7
USGS Decatur	691	1.6	1.4	2.7
USACE Blair	648.3	1.4	1.1	2.2
USGS Omaha	615.9	1.4	1.1	2.2
USACE Plattsmouth	691.5	0.7	0.5	1.8
USGS Nebraska City	562.6	0.9	0.4	1.5
USACE Brownville	535.3	0.6	0.4	2
USGS Rulo	498.1	0.6	0.4	1.5
USGS St. Joseph	448.2	0.5	n.m.	1.4
USGS Kansas City	366.1	0.3	n.m.	1.1
USACE Napoleon	328.7	0.2	n.m.	0.9
USGS Waverly	293.4	0	n.m.	0.8
USACE Glasgow	226.3	0	n.m.	0.8
USGS Boonville	197.1	0	n.m.	0.7
USACE Jefferson City	143.9	0	n.m.	0.8
USGS Hermann	97.9	0	n.m.	1.9*
USGS St. Charles	28.2	0	n.m.	1.4*

n.m. not measureable (could not be objectively measured)
Note that the 2006 data spring rises were measured mainly through staff gage readings and influences of precipitation and upstream flows on the spring rise were not considered
*Likely contains measurement problems and was removed
CSR – Created spring rise

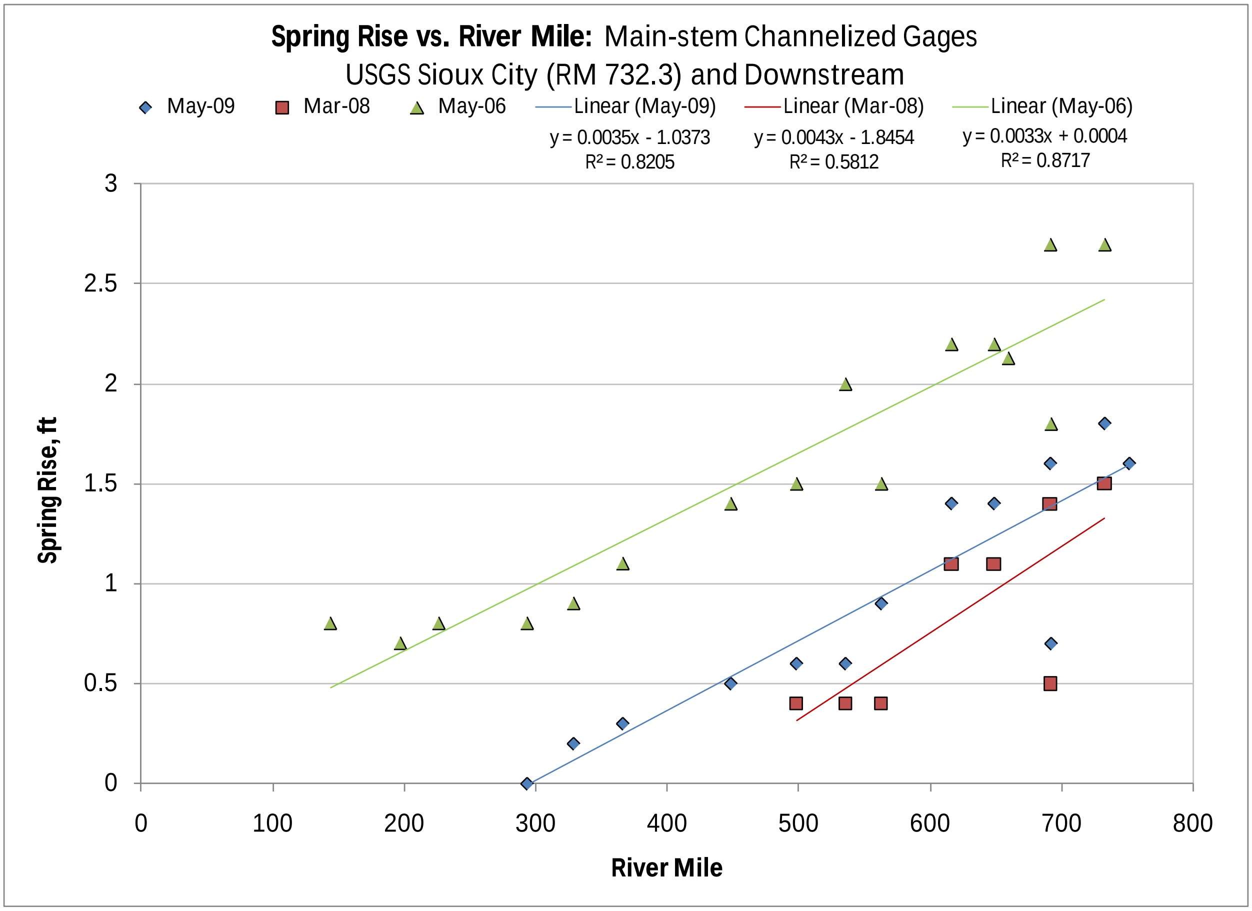

Figure 9.2.1 – Spring rise stage attenuation, SR vs. RM (May 2006, March 2008, and May 2009)

10.0 Monitoring Sites Analysis

10.1 Analysis Contents

Section 10 documents the effects of the created spring pulse and natural spring rises on drainage sites along the Missouri River. In the case of each site, the following information is provided where applicable:

§ Location Map

Map showing site and gage locations

§ Surveyed Elevations

Surveyed elevations including drainage structure inlet and outlet invert elevations and field and berm elevations

§ Measurement of Created Spring Rise

Change in stage at site (created spring rise) produced by the created spring pulse. In the case of gages directly on the Missouri River, the full created spring rise is captured. However, for gages on drainage channels tributary to the Missouri River, only a portion of the created spring rise (called the partial spring rise) is often captured due to the elevation difference between the gage and the Missouri River. Partial spring rises are noted.

§ Site Rainfall

USACE precipitation data are shown in the case of automatic gage sites like Sioux City and Kansas City if it was available for the full 2009 monitoring period. These gage data were referenced from the USACE database in either daily or hourly intervals and processed into daily intervals. NWS experimental-multi-sensor data are used in the case of supplemental sites and for automatic gage sites without precipitation data available for the period of record.

§ Spring Rise Graph

Graph identifying the created spring rise along with the site field or flood stage elevation. Field elevations are provided for supplemental sites on inland drainage. Flood stage elevations are shown for automatic sites along the Missouri River. In some cases, the flood stage is not shown directly on the graph but annotated at the top if the stage plots outside the graph.

§ Full Monitoring Record Graph

Graph showing the full monitoring record of the site with the spring-pulse release date shown and the navigation travel time to the site. Travel time at navigation flows was used to help identify the created spring rise.

§ Inlet- and Outlet-Elevation Graph

Graph showing the inlet and outlet invert elevations of the drainage structure at the site

§ Surveyed Elevation Graph

Graph of surveyed field or drainage ditch berm elevations

§ Natural Spring Rise Impact Graph

Graph of site socioeconomic impacts due to natural spring rises. Site socioeconomic impacts include overbank flooding, pumping in response to high Missouri River flows, and gate closures.

§ Natural Spring Rise Impact-Flow Threshold Graph

Graph showing the elevations and flows used to estimate impact-flow thresholds. Flow records used to determine the impact flow thresholds were estimated through three methods: 1) interpolation from flow records at USGS site along the Missouri River lagged to the site, 2) lagging an upstream or downstream USGS gage record to the site, and 3) lagging major gauged tributary flow records to the Missouri River and adding them to USGS gauge flow records along the main stem of the Missouri River. In each case, flows were lagged to the site so the change in stages matched closely with changes in flows at the site. Lag times were based on navigation and bank-full travel times documented in the Reservoir Control Center's (RCC) *Travel Time below Gavins Point Dam to Mouth of St. Louis* (2006).

§ Drainage Structure Inlet- and Outlet Flow Threshold Graphs

Graphs showing the elevations and flows used to estimate inlet- and outlet-flow thresholds. In the case of some inlet gages, the water-surface elevation never dropped low enough to determine the inlet-flow threshold from the LS data. In these cases, the inlet-flow threshold was determined using the water-surface elevation at the RS gage where possible.

Graphs showing the elevations and flows used to estimate impact-, inlet-, and outlet-flow thresholds with 2008 data

§ Summary Tables

Tables summarizing estimated flow thresholds, site results, and socioeconomic impacts for both 2008 and 2009. The spring pulse flow at each site is estimated from Equations 9.1 and 9.2 shown in Section 9 and compared with the total flow estimated at the site.

Note that some sites field and water surface elevations were determined in the NGVD 29 datum and some were determined in the NAVD 88 datum.

10.2 Gage Types

Four main gage types are considered: river, levee, ditch, and side ditch. Figure 10.2.1 shows the general layout of these four types of gages.

River gages include automatic and supplemental gages installed directly on the Missouri River. Some examples of river gages are USACE Gayville, USGS Omaha, Pelican Point, and Brunswick Terminal. The purpose of monitoring these gages was to track the passage of the created spring pulse along the Missouri River and monitor the affects of other natural flows (natural spring rises) at sites. The rise created by the spring pulse at these sites is identified at these gages and the flood stage provided where applicable.

Levee gages are mainly supplemental gages installed either on the riverside of levees near the drainage structure outlet or on the landside of levees near the drainage structure inlet. Examples include California Bend, L-575 Structure No. 23, Holt County LD No. 9, and MO Valley DLD. The purpose of monitoring these sites was to identify socioeconomic impacts to landowners. Socioeconomic impacts include pumping, gate closures, and overbank flooding. Impact flow thresholds and inlet and outlet-flow thresholds were identified at these sites. Flow thresholds are given in terms of flows in the Missouri River at the river mile of the site and in

terms of flows at the closest upstream automatic Missouri River gage with flow data. Field elevations were surveyed at these sites in 2009 to help quantify impacts.

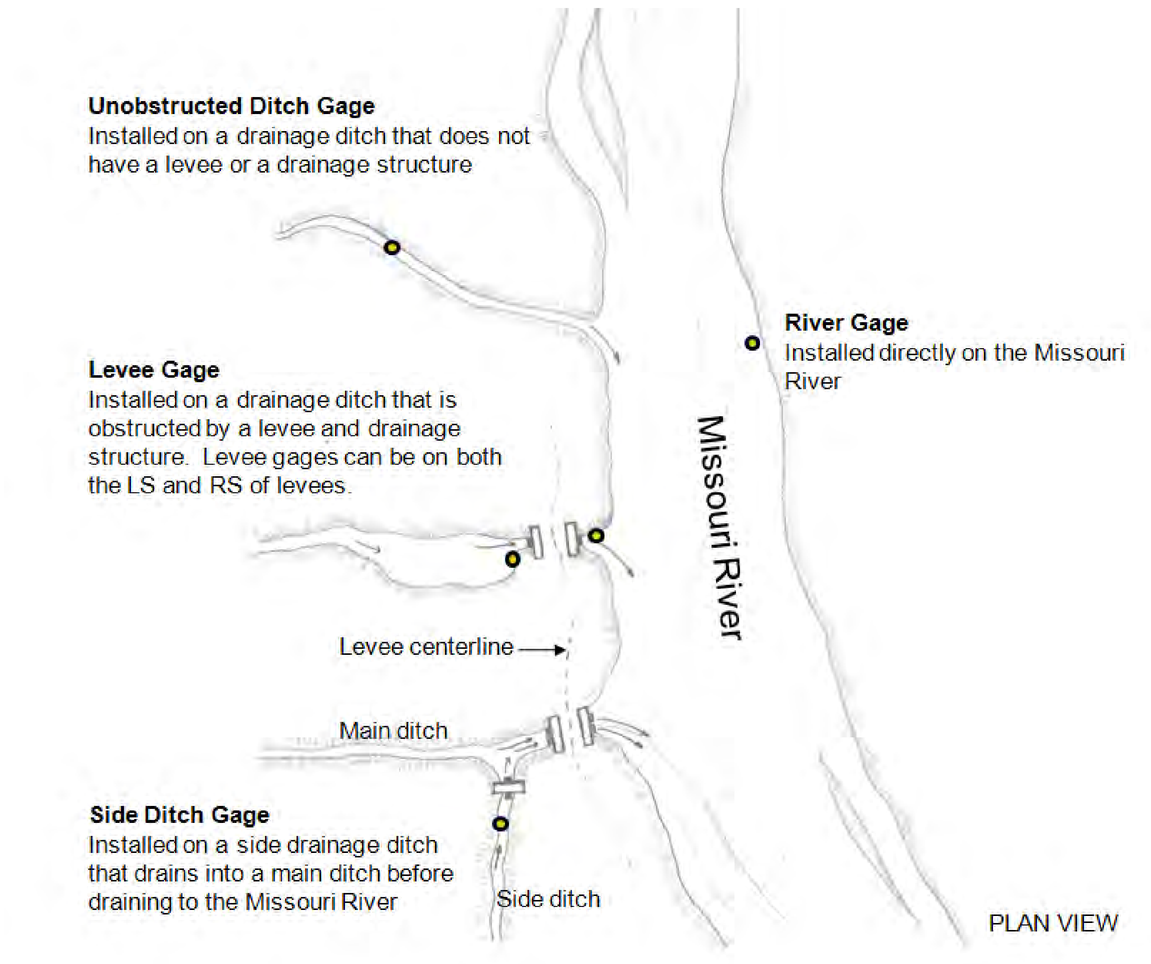

Figure 10.2.1 – Monitoring-site types

Unobstructed drainage ditch gages do not have levees or drainage structures. The County Line Ditch site is an example of an unobstructed drainage ditch. Impact-flow thresholds are identified at these sites where possible. Field elevations were surveyed at these sites in 2009 to help quantify impacts.

Side ditch gages are installed on the landside of ditches draining into a main ditch that drains to the Missouri River. Examples include the side ditches of L-246 Palmer Creek and L-246 Dalton Ditch. Impact flow thresholds cannot be quantified at these locations because they are more affected by water levels in the main ditch than flows in the Missouri River.

10.3 USACE Gavins Point Dam

The USACE Missouri River gage at Gavins Point Dam is located at the tail waters of Gavins Point Dam in South Dakota at river mile 811.1 (Figure 10.3.1). Figure 10.3.2 shows the spring pulse release from Gavins Point Dam on May 18, 2009. The rise produced by the created spring pulse was 1.4 ft.

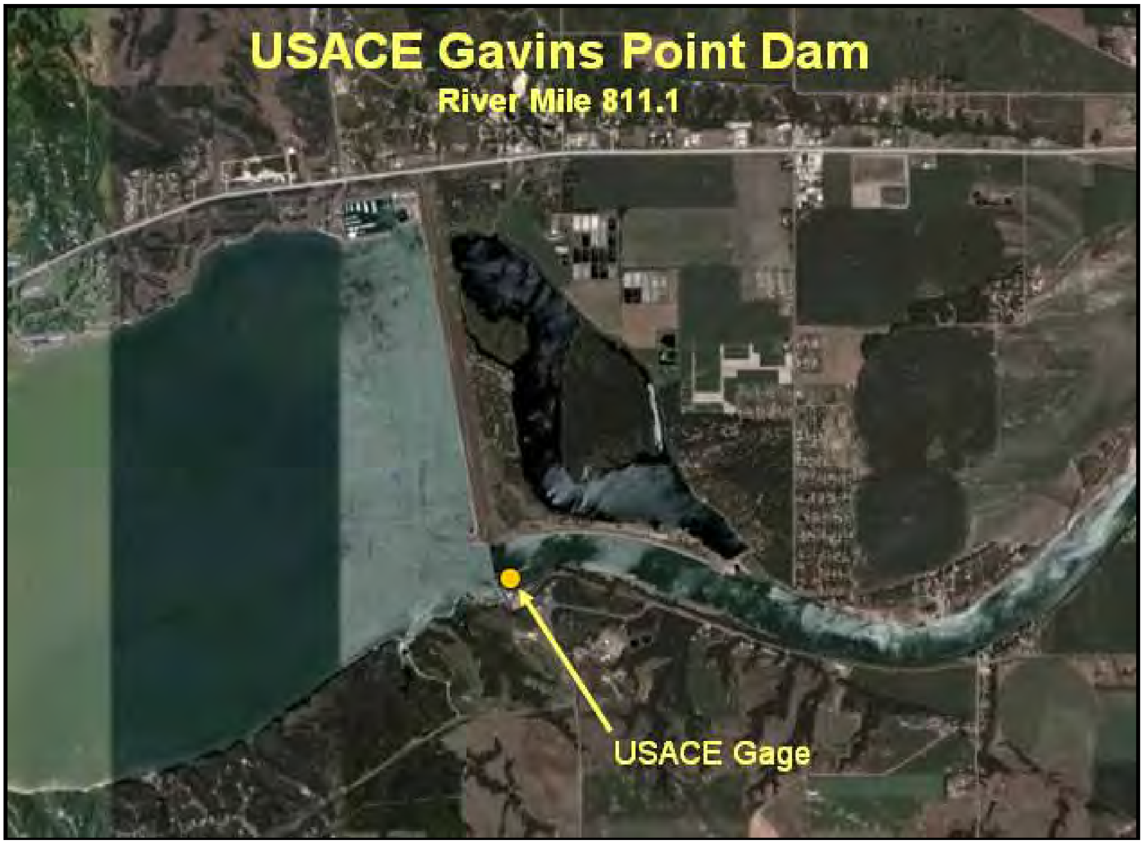

Figure 10.3.1 – USACE Gavins Point Dam location

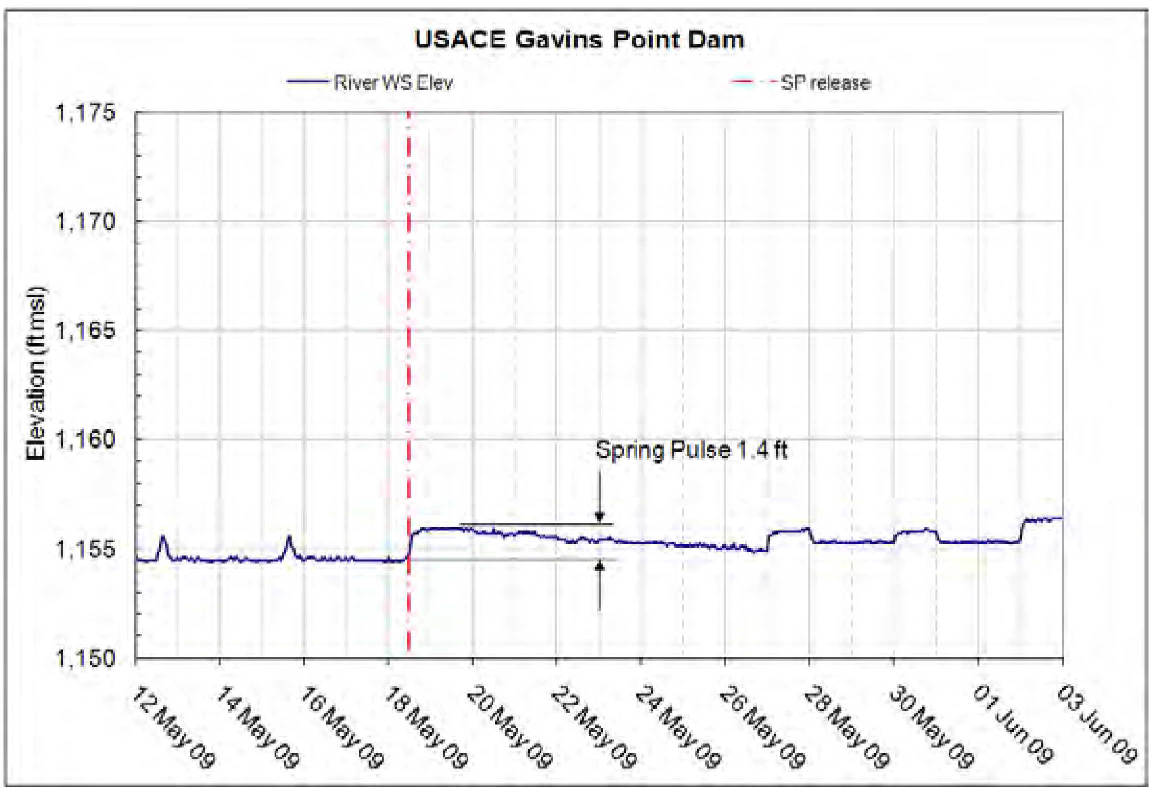

Figure 10.3.2 – Spring pulse at USACE Gavins Point Dam

10.4 USGS Yankton

The USGS Missouri River Yankton gage is located on the left bank of the Missouri River just south of Yankton, SD at river mile 805.8 (Figure 10.2.1). Figure 10.4.2 shows the rise created by the spring pulse release from Gavins Point Dam. The created spring rise at this site was 1.2 ft. Figure 10.4.3 shows the full monitoring record with the travel time of the spring pulse noted. The flow in the Missouri River at the time of the spring pulse was 23 kcfs.

Figure 10.4.1 – USGS Yankton location

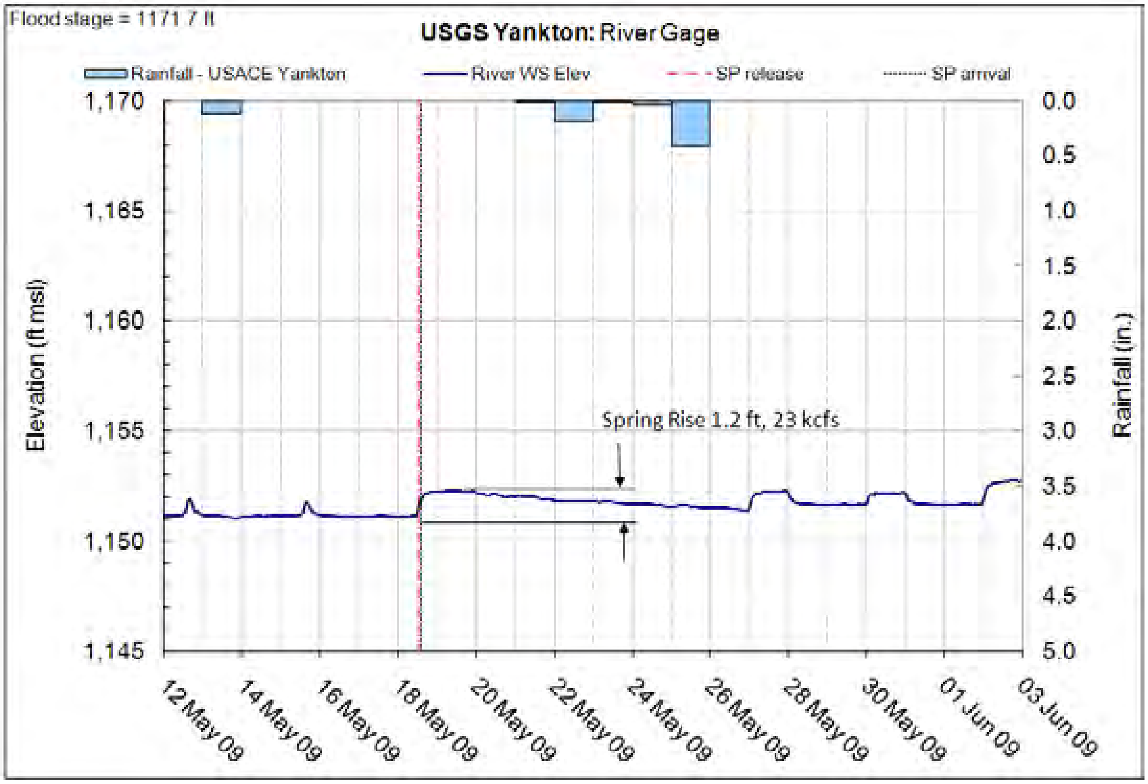

Figure 10.4.2 – Spring rise at USGS Yankton

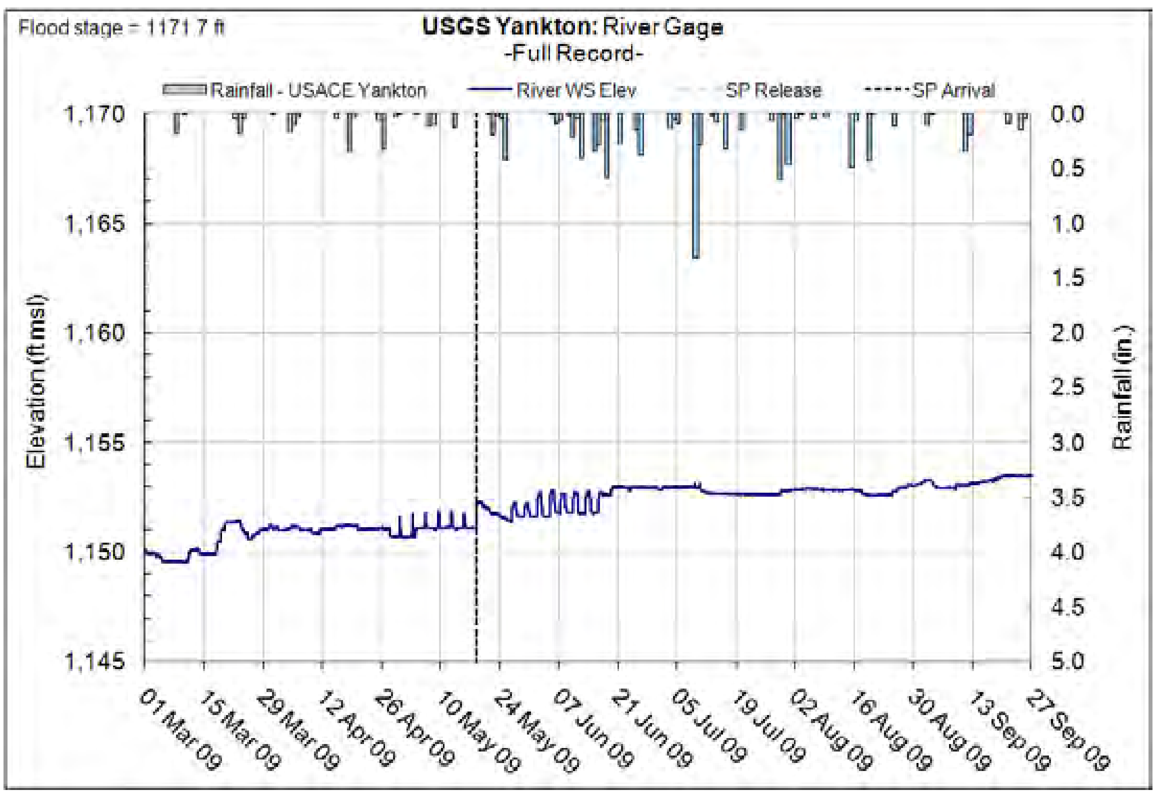

Figure 10.4.3 – Full monitoring record at USGS Yankton

10.5 USACE Gayville

The USACE Missouri River Gayville gage is located southwest of Gayville, SD at river mile 796.0 (Figure 10.5.1). Figure 10.5.2 shows the created spring rise produced by the spring pulse released from Gavins Point Dam. The created spring rise at this site was 0.9 ft. Figure 10.5.3 shows the full monitoring record with the travel time of the spring pulse noted.

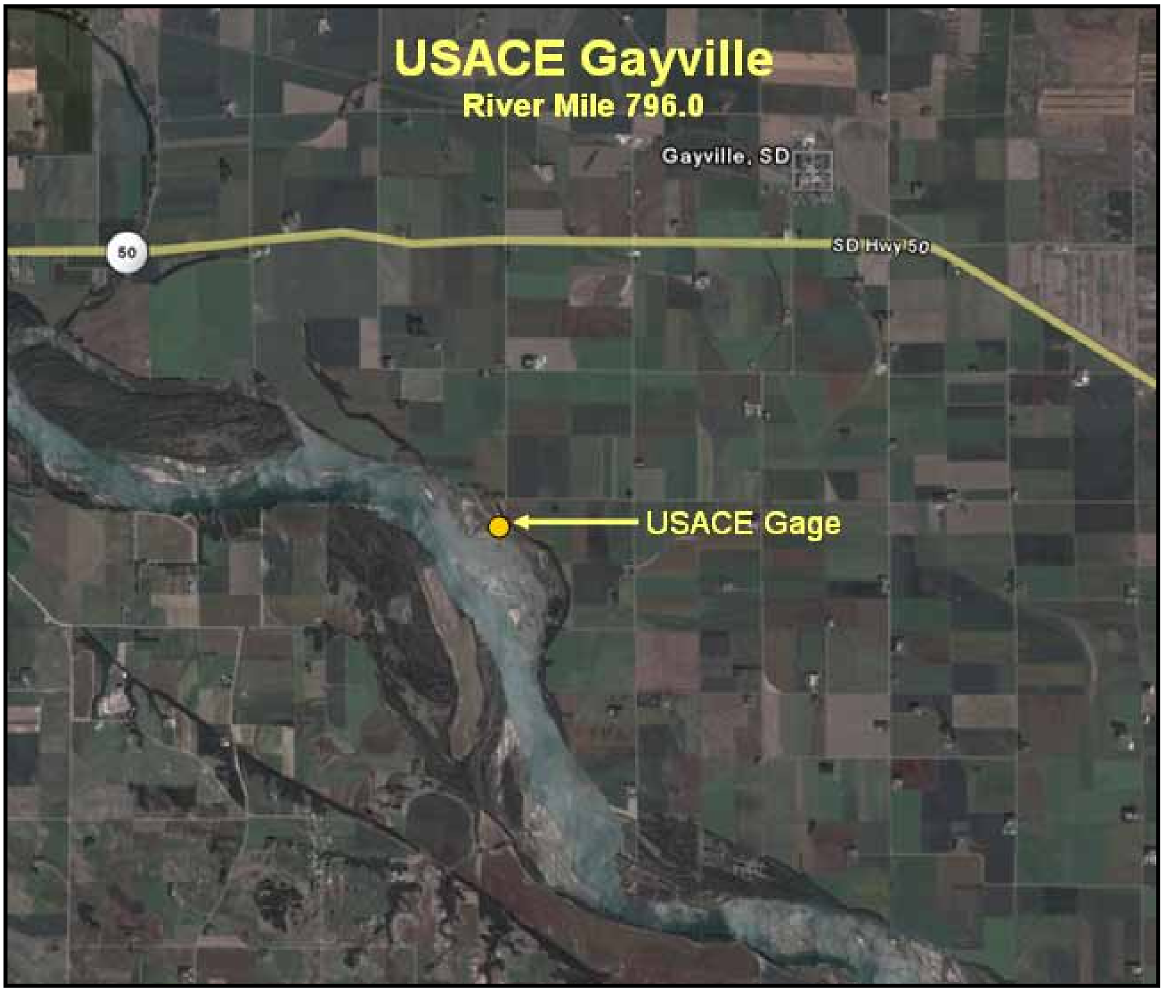

Figure 10.5.1 – USACE Gayville location

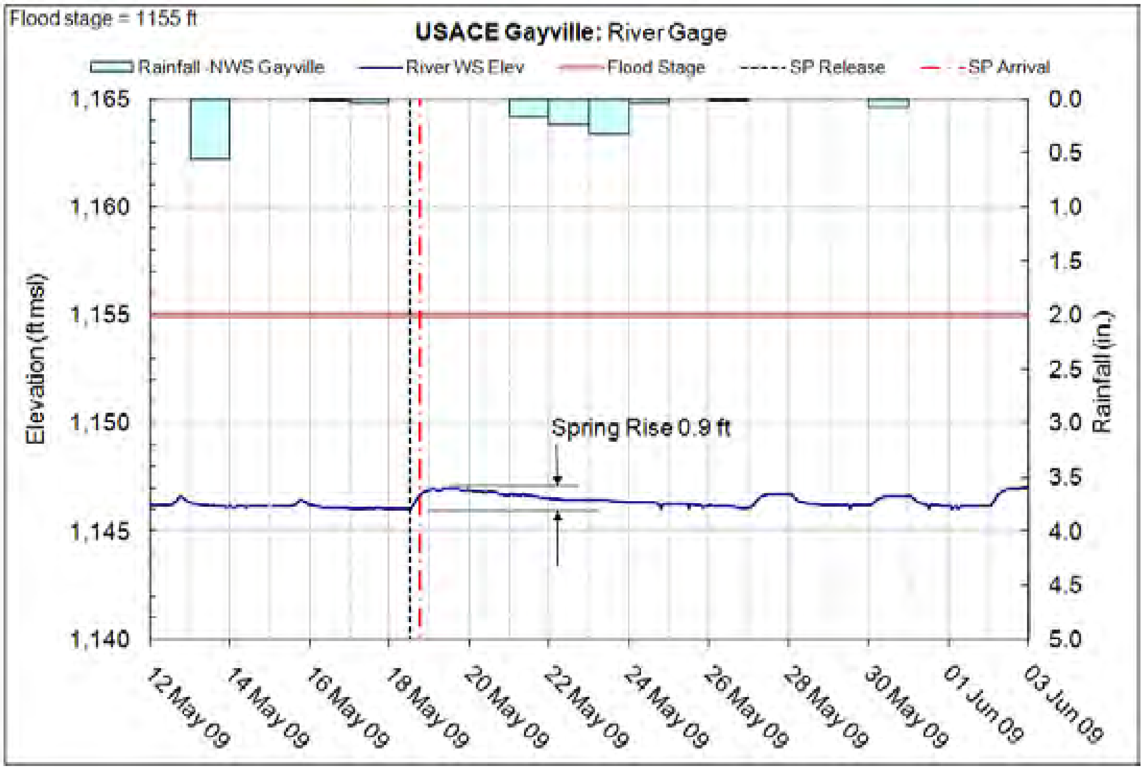

Figure 10.5.2 – Spring rise at USACE Gayville

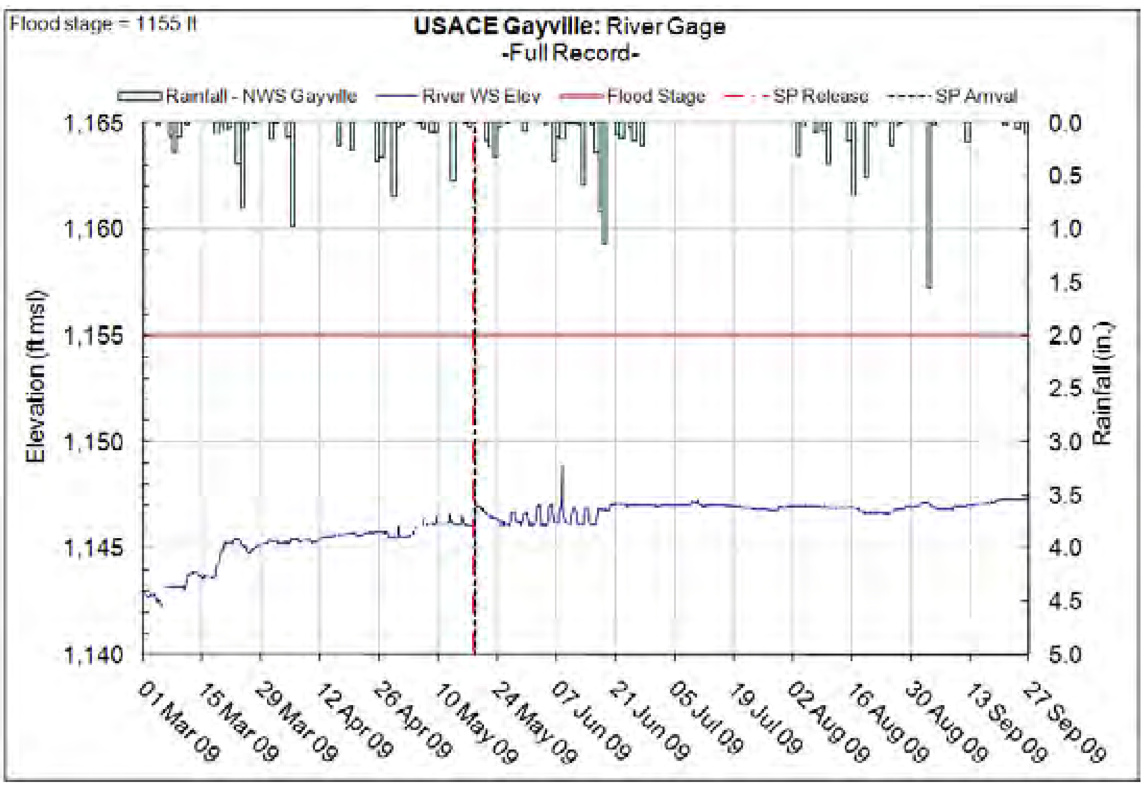

Figure 10.5.3 – Full monitoring record at USACE Gayville

10.6 USGS Maskell

The USGS Missouri River Maskell gage is located on the right bank of the Missouri River at river mile 775.6 downstream of the South Dakota Highway 19/15 Bridge (Figure 10.6.1). Figure 10.6.2 shows the created spring rise produced by the spring pulse released from Gavins Point Dam. The created spring rise at this site was 1 ft. Figure 10.6.3 shows the full monitoring record with the travel time of the spring pulse noted.

Figure 10.6.1 – USGS Maskell location

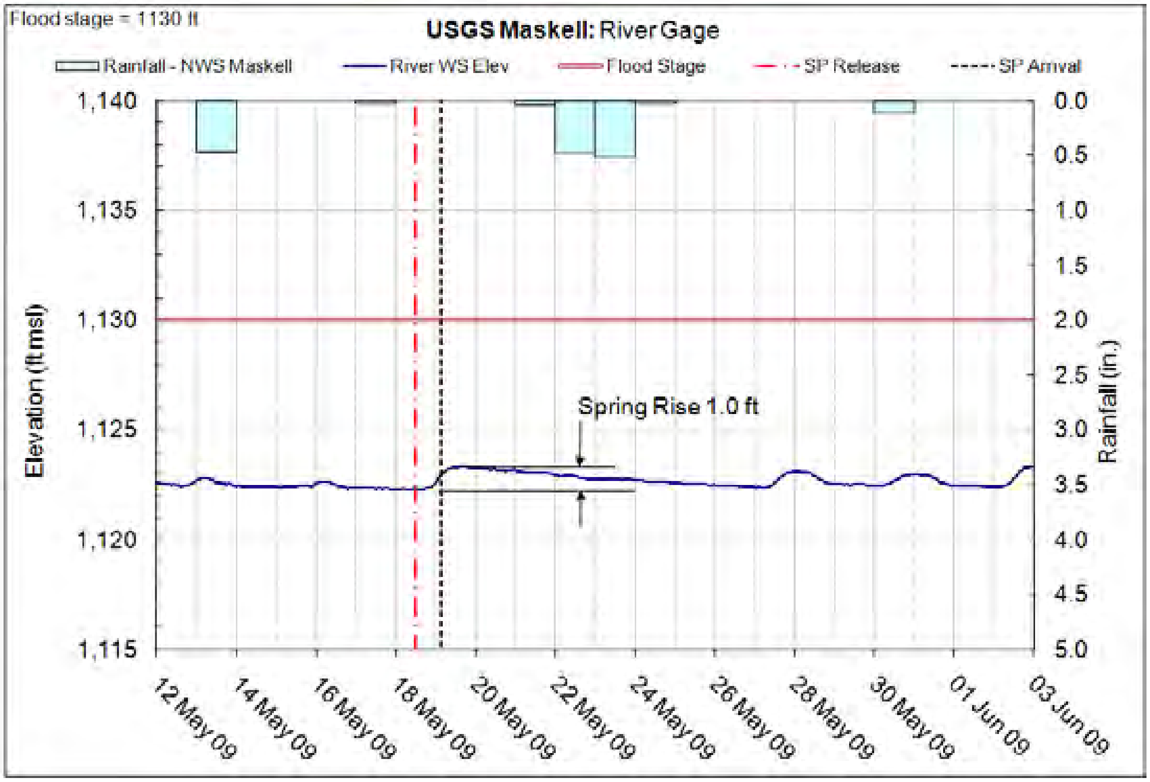

Figure 10.6.2 – Spring rise at USGS Maskell

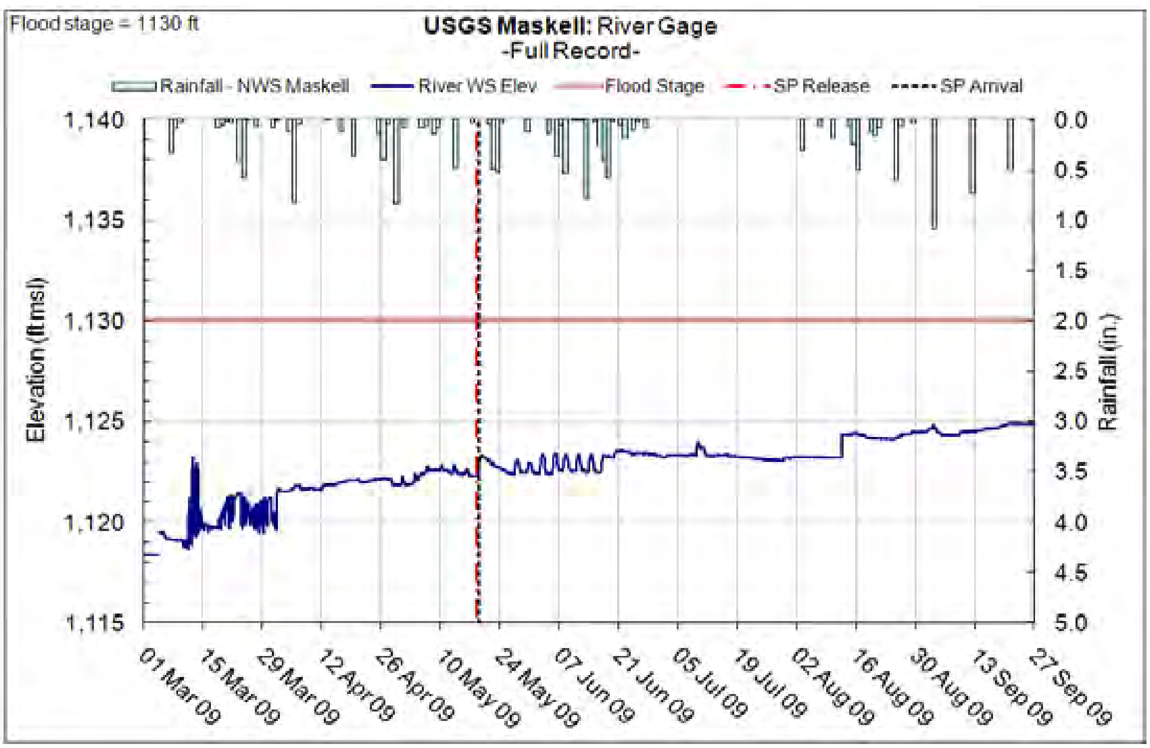

Figure 10.6.3 – Full monitoring record at USGS Maskell

10.7 USACE Ponca

The USACE Missouri River Ponca gage is located on the right bank of the Missouri River at river mile 751.0 about 1.3 miles to the northeast of Ponca, NE (Figure 10.7.1). Figure 10.7.2 shows the created spring rise produced by the spring pulse released from Gavins Point Dam. The created spring rise at this site was 1.6 ft. Figure 10.7.3 shows the full monitoring record with the travel time of the spring pulse noted.

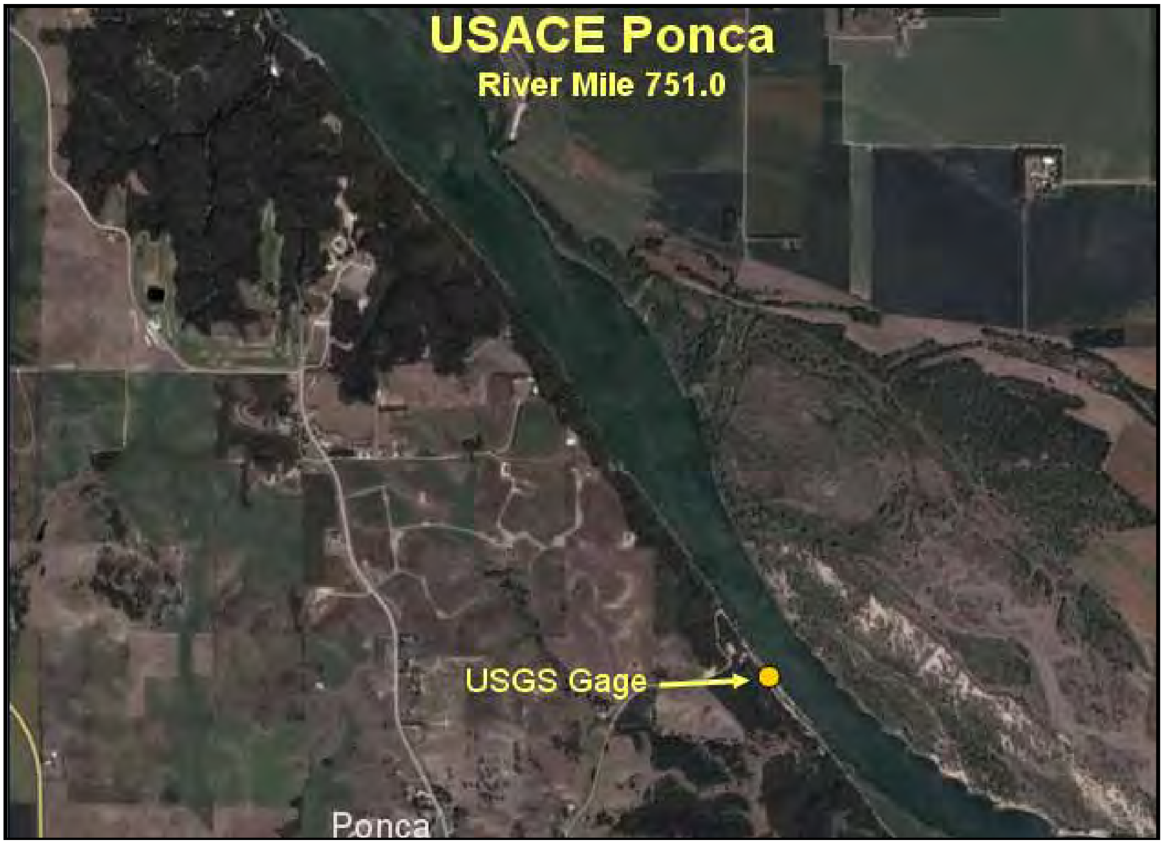

Figure 10.7.1 – USACE Ponca location

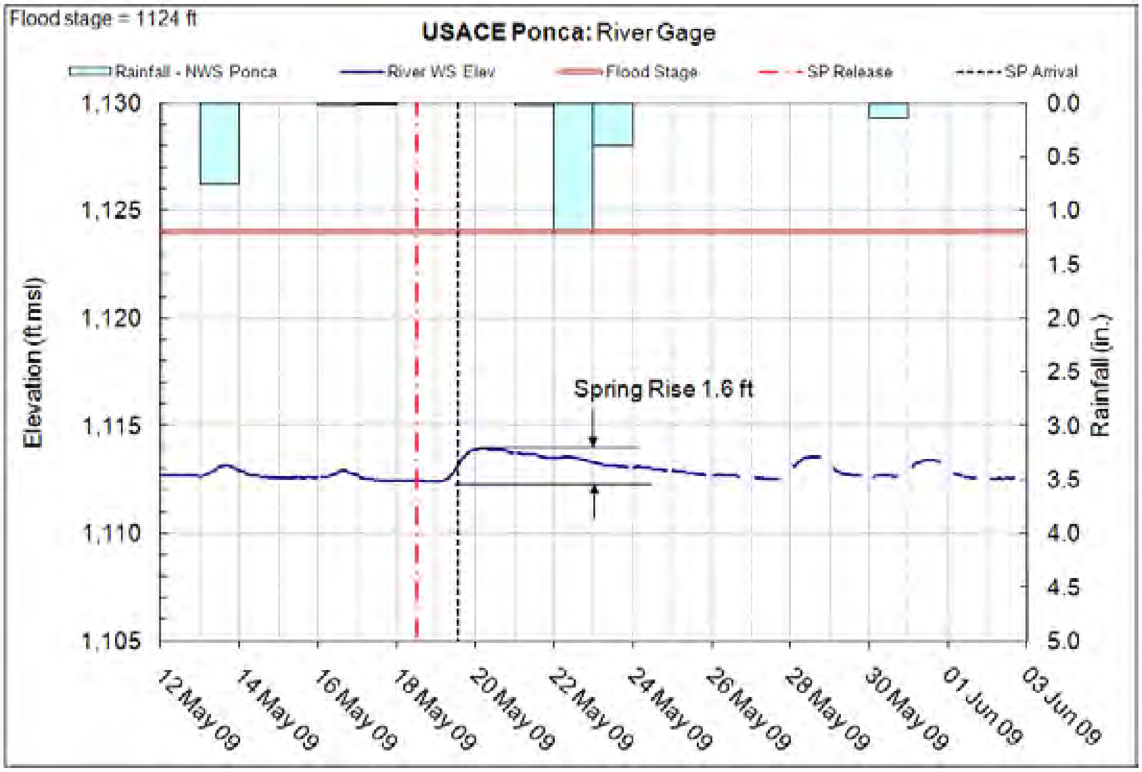

Figure 10.7.2 – Spring rise at USACE Ponca

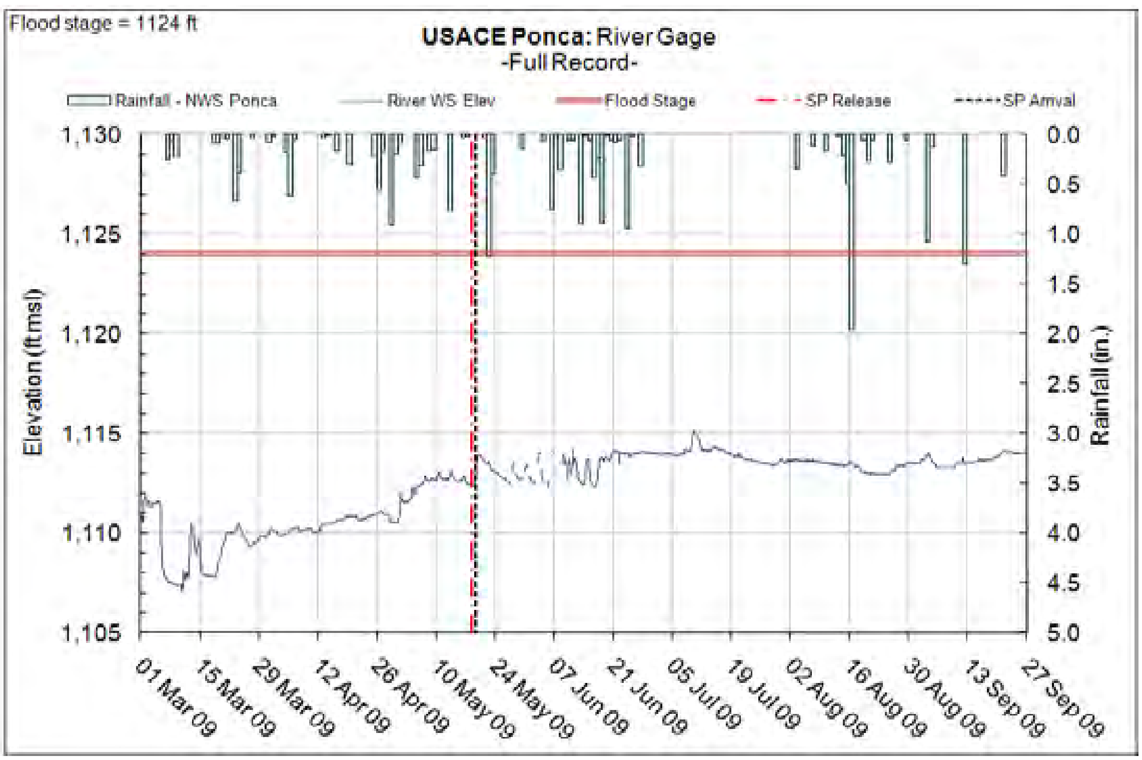

Figure 10.7.3 – Full monitoring record at USACE Ponca

10.8 USGS Sioux City

The USGS Missouri River Sioux City gage is located at river mile 732.3 on the right bank of the Missouri River just downstream of the Veteran's Bridge (Figure 10.8.1). Figure 10.8.2 shows the created spring rise produced by the spring pulse released from Gavins Point Dam. The created spring rise at this site was 1.8 ft. Figure 10.8.3 shows the full monitoring record with the travel time of the spring pulse noted.

Figure 10.8.1 – USGS Sioux City location

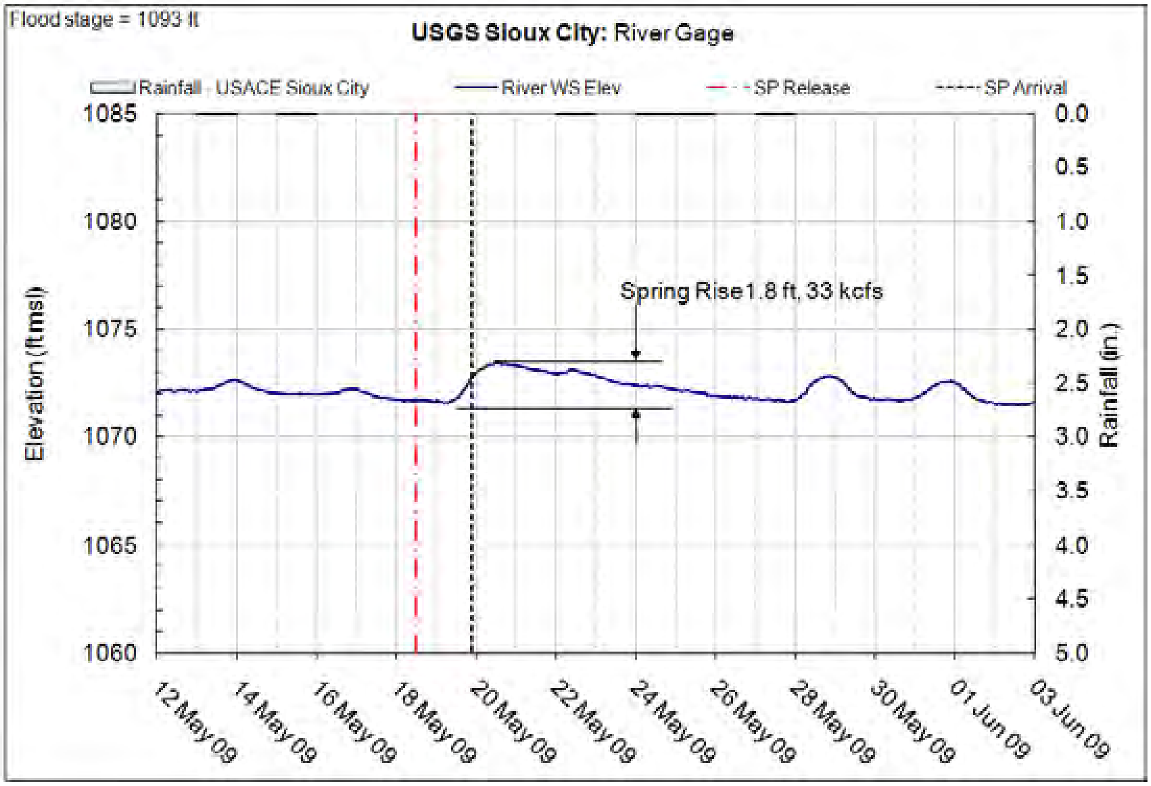

Figure 10.8.2 – Spring rise at USGS Sioux City

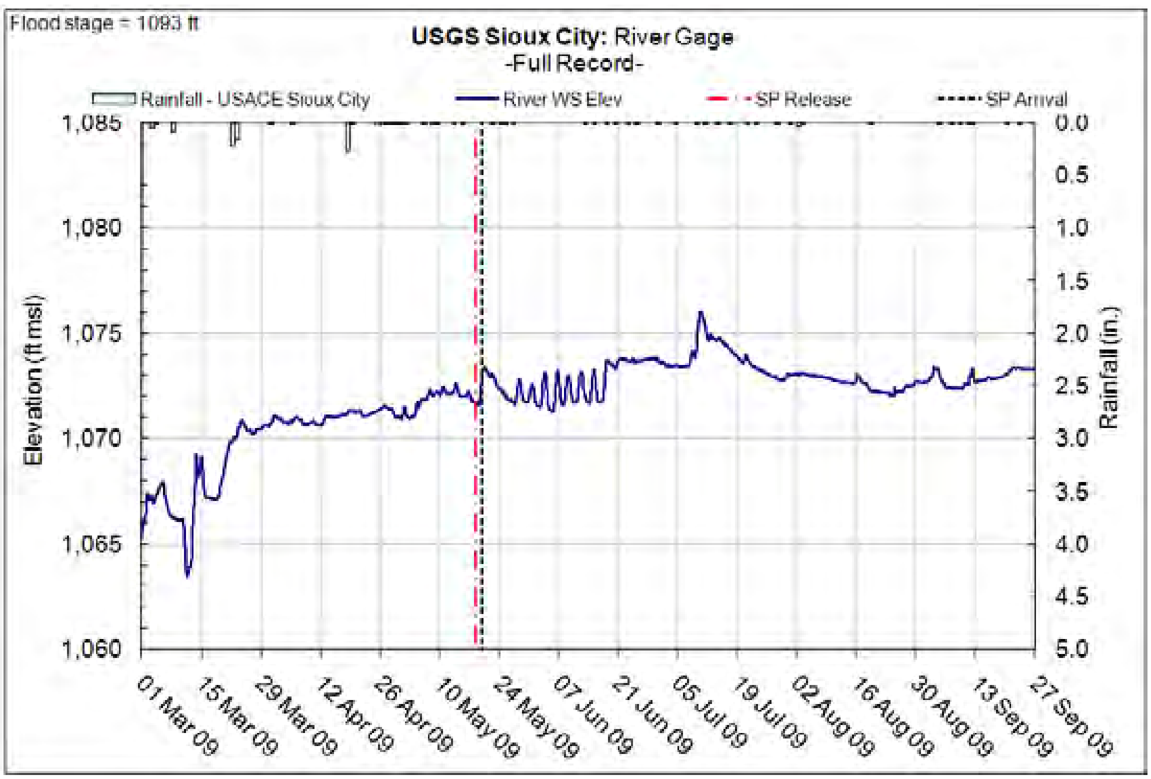

Figure 10.8.3 – Full monitoring record at USGS Sioux City

10.9 USGS Decatur

The USGS Missouri River Decatur gage is located at river mile 691.0 on the left bank of the Missouri River east of Decatur (Figure 10.9.1). Figure 10.9.2 shows the created spring rise produced by the spring pulse released from Gavins Point Dam. The created spring rise at this site was 1.6 ft. Figure 10.9.3 shows the full monitoring record with the travel time of the spring pulse noted.

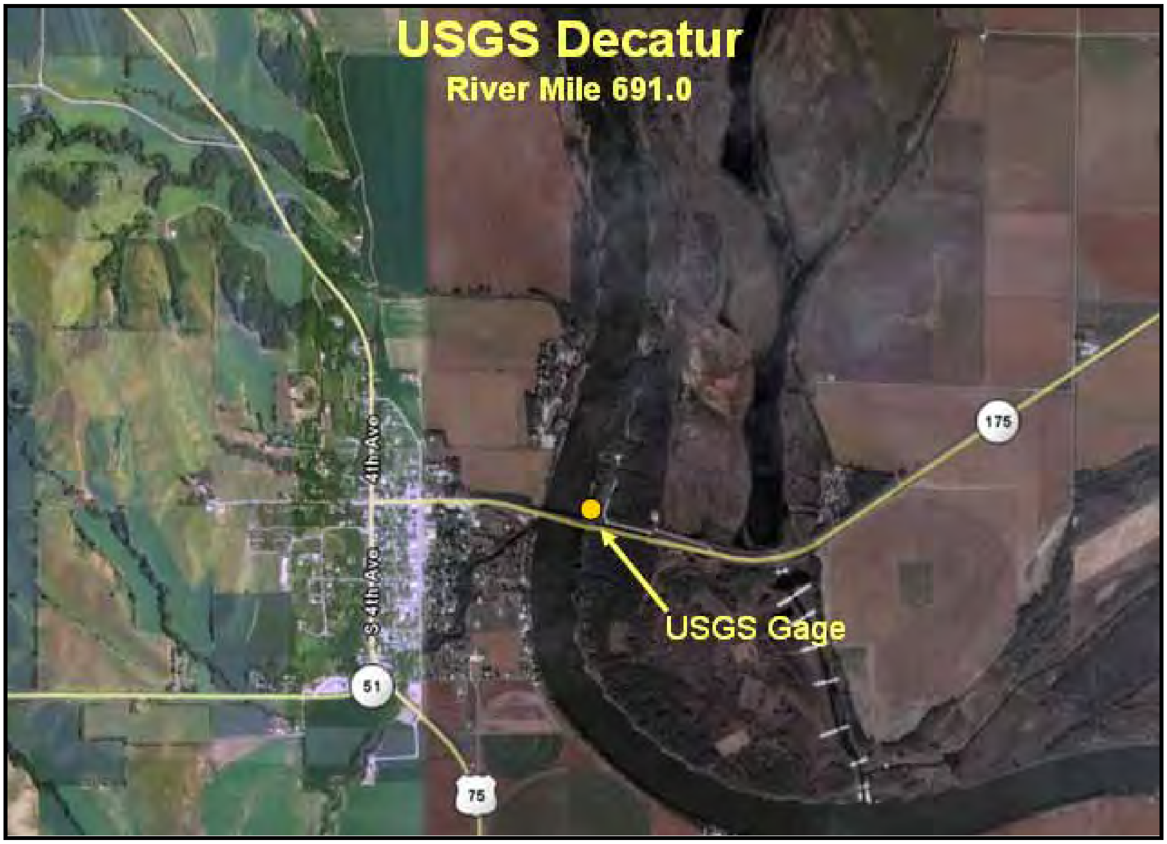

Figure 10.9.1 – USGS Decatur location

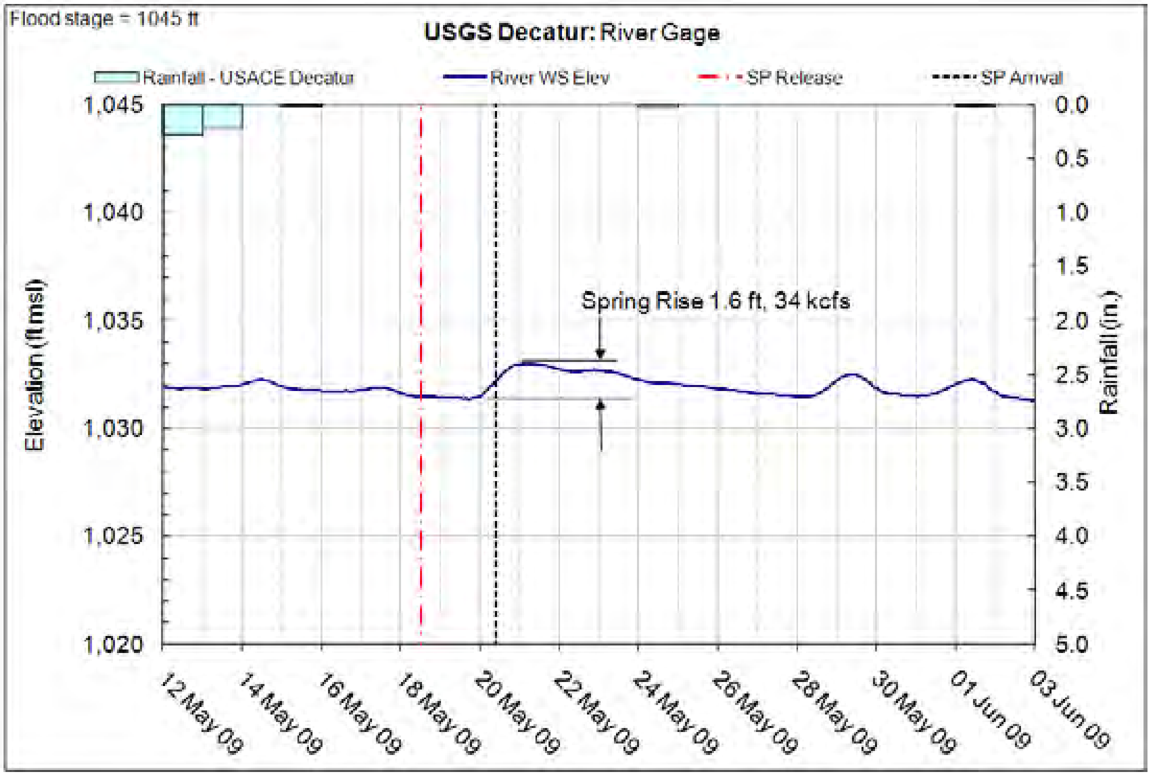

Figure 10.9.2 – Spring rise at USGS Decatur

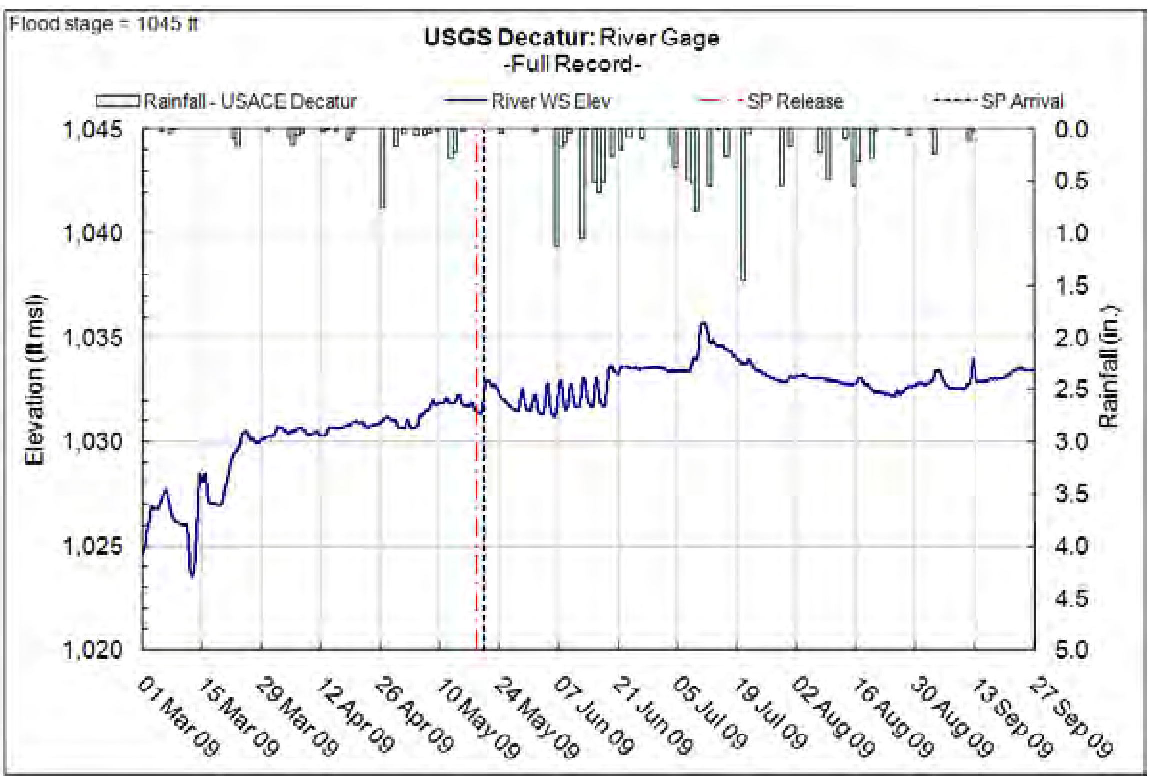

Figure 10.9.3 – Full monitoring record at USGS Decatur

10.10 Pelican Point

The Pelican Point site is located in Burt County, NE approximately 7 miles northeast of the town of Tekamah and upstream of River Sioux, IA (Figure 10.10.1). This supplemental gage was installed on the right bank of the Missouri River at river mile 672.7 to monitor created and natural spring rises. Both a staff gage and a data logger were installed in the sandy bank of this site near a wing dike (Figure 10.10.2). Flows were estimated at the site by lagging the flow records of USGS Decatur and USGS Omaha to the site based on peaks and then interpolating flows based on river miles.

Results and Discussion

- Table 10.10.1 summarizes the results for the May 2009 and March 2008 created spring rises at Pelican Point.
- Figure 10.10.3 shows the spring pulse release and its arrival time to the site. The rise created by the May spring pulse was 1.4 ft. Based on the attenuation analysis, the spring pulse accounts for 5.6 kcfs of the total 34-kcfs Missouri-River flow at this river mile, or 16% of the total flow.
- Figure 10.10.4 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site shown.

Conclusions

Based on the attenuation analysis, the spring pulse accounts for 5.6 kcfs of the total 34-kcfs Missouri-River flow at this river mile, or 16% of the total flow.

Table 10.10.1 – Pelican Point results

Spring Pulse from Gavins Point Dam	***May-09***	***Mar-08***
Created spring rise, ft	1.4	1.1
Estimated created spring rise flow, kcfs	5.6	3.0
Estimated MR flow at site, kcfs	34	23
% of MR flow	16	13

Observed Impacts
River gage; no impacts documented.

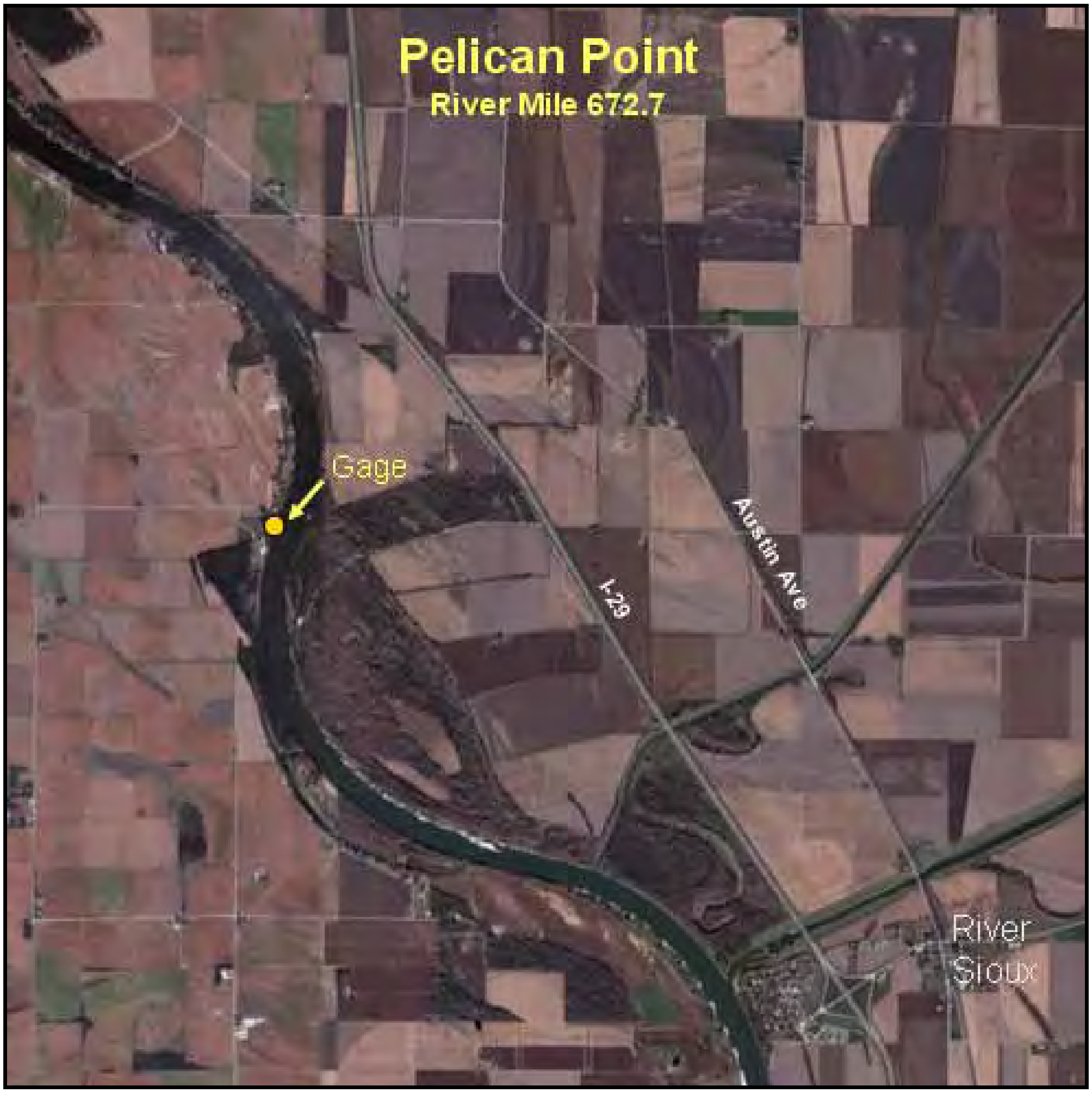

Figure 10.10.1 – Pelican Point location

Figure 10.10.2 - Pelican Point gages. Supplemental gage (left) and staff gage (right).

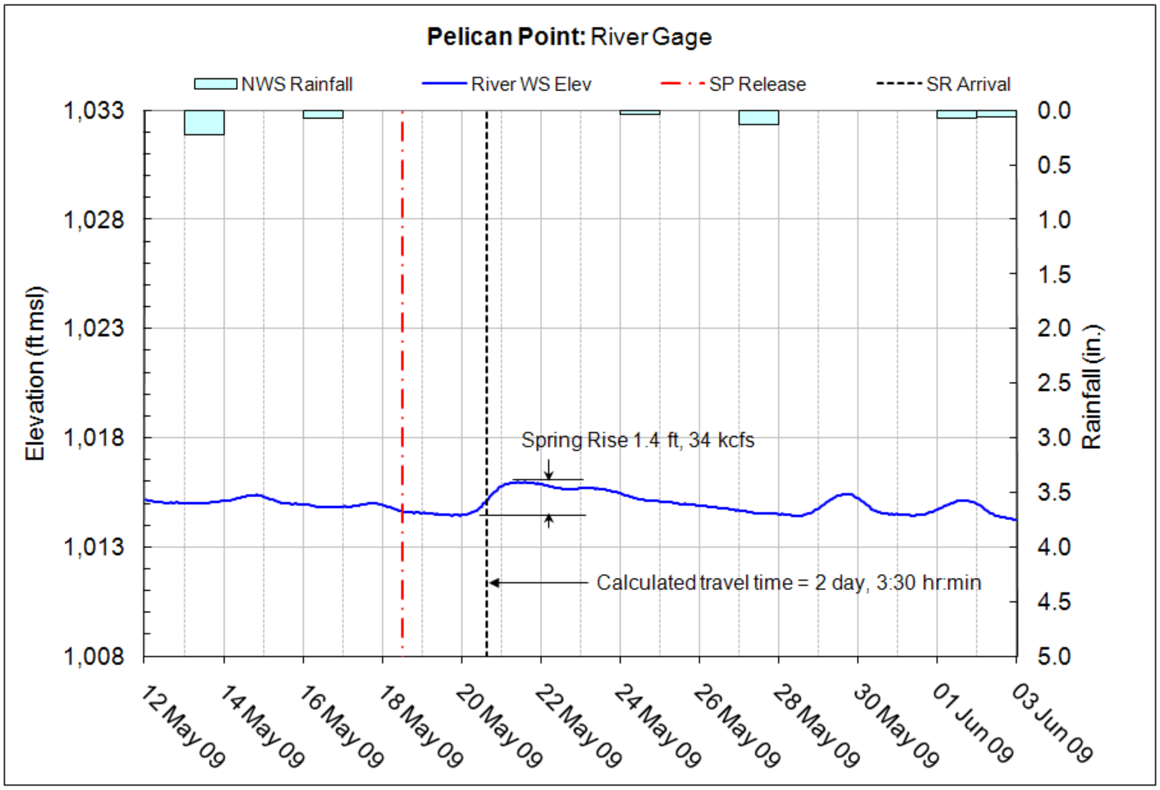

Figure 10.10.3 – Spring rise at Pelican Point

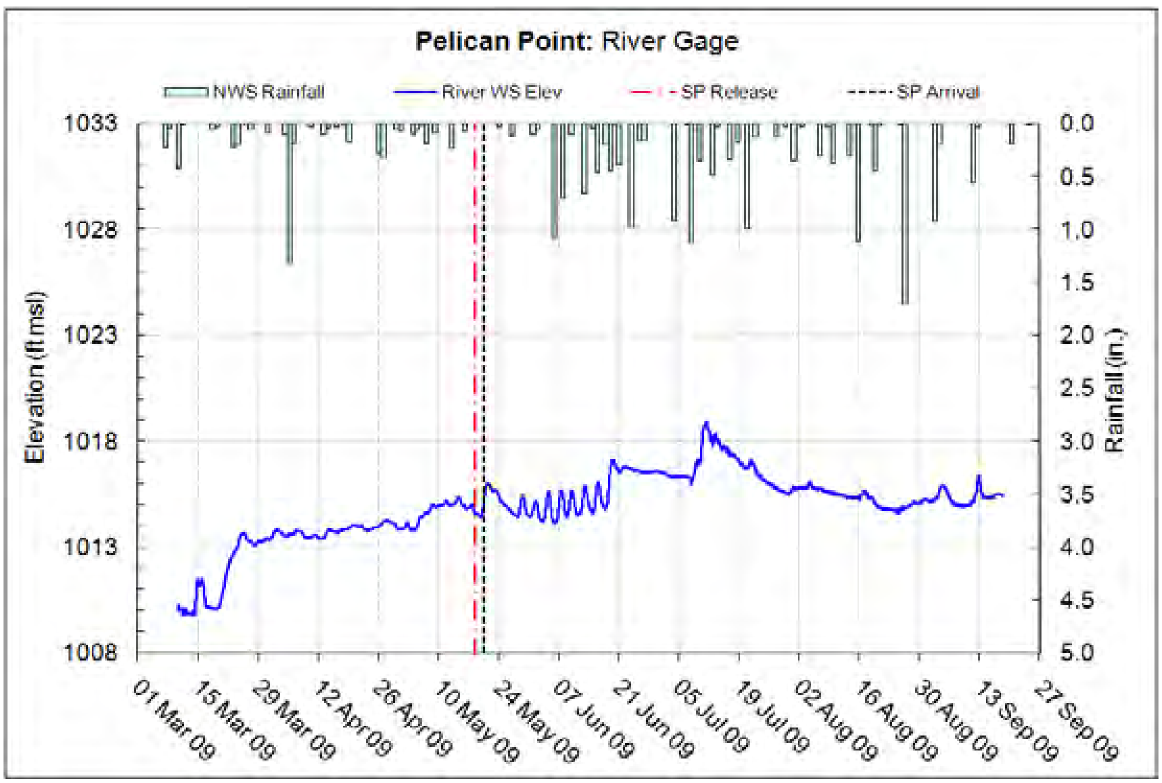

Figure 10.10.4 – Full monitoring record at Pelican Point

10.11 County Line Ditch

County Line Ditch, also called Herman Ditch, is located approximately 6 miles south of Tekamah along the Burt and Washington County lines (Figure 10.11.1). This ditch drains into the right bank of the Missouri River near river mile 659.0 and the Peterson Cutoff bend. The County Line Ditch was selected to monitor and evaluate the effects of spring rises on backwater extending upstream in an unobstructed drainage channel. Two gages were installed to monitor backwater effects: a downstream (DS) gage near the confluence of the ditch with the Missouri River and an upstream (US) gage approximately 3-miles upstream of the confluence. Both gage stations consisted of a staff gage and data logger. The US site was moved 116 ft downstream from the 2008 site.

Field elevations were surveyed in 2009. The surveyed elevation of the field on the left bank near the US gage was 1013.2 ft. The left bank is the lower of the two banks. The elevation of the bank near the DS gage is 1009.4 ft. The elevation of the bank at the US site (1013.2 ft) and the elevation of the bank at the DS site (1009.4 ft) were used in the analysis and figures. All elevations are in the NGVD 29 datum. Flows were estimated at the site by lagging the flow records of USGS Decatur and USGS Omaha to the site based on peaks and then interpolating flows based on river miles.

Results and Discussion

- Table 10.11.1 summarizes the results for the May 2009 and March 2008 created spring rises at County Line Ditch. Table 10.11.2 summarizes the socioeconomic impacts produced by natural spring rises at the site in May 2009 and March 2008.
- Figure 10.11.3 shows the spring pulse release on May 18 and its arrival time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise created by the spring pulse was 1.3 ft. Based on the attenuation analysis, the spring pulse accounts for 5.4 kcfs of the total 34-kcfs Missouri-River flow at this river mile, or 16% of the total flow.
- Figure 10.11.4 shows the full monitoring record with the time of the May spring pulse's release and its arrival time at the site shown.
- Inlet and outlet invert elevations were not available at this site because it has no drainage structure.
- Figure 10.11.5 shows the full monitoring record with the surveyed field elevations. No socioeconomic impacts were observed at this site. The figure also shows the gage-sensitivity thresholds for the US and DS gages. Flows in the Missouri River had to be at or above 17 kcfs to submerge the DS gage and at 23 kcfs or above to submerge the US gage.
- Figure 10.11.6 shows the full monitoring record of 2008 with the field elevations surveyed in 2009. After late May, the DS elevation is consistently higher than the US elevation. This is likely due to a slight amount of drift in the calibration of the data logger. No socioeconomic impacts were observed.

Conclusions

No socioeconomic impacts were created at this site by either the created spring pulse or natural spring pulses in May 2009. The rise created by the created spring pulse was 1.3 ft. Inlet and outlet-flow thresholds could not be determined because the site has no drainage structure. Based on the attenuation analysis, the spring pulse accounts for 5.4 kcfs of the total 34-kcfs Missouri-River flow at this river mile, or 16% of the total flow.

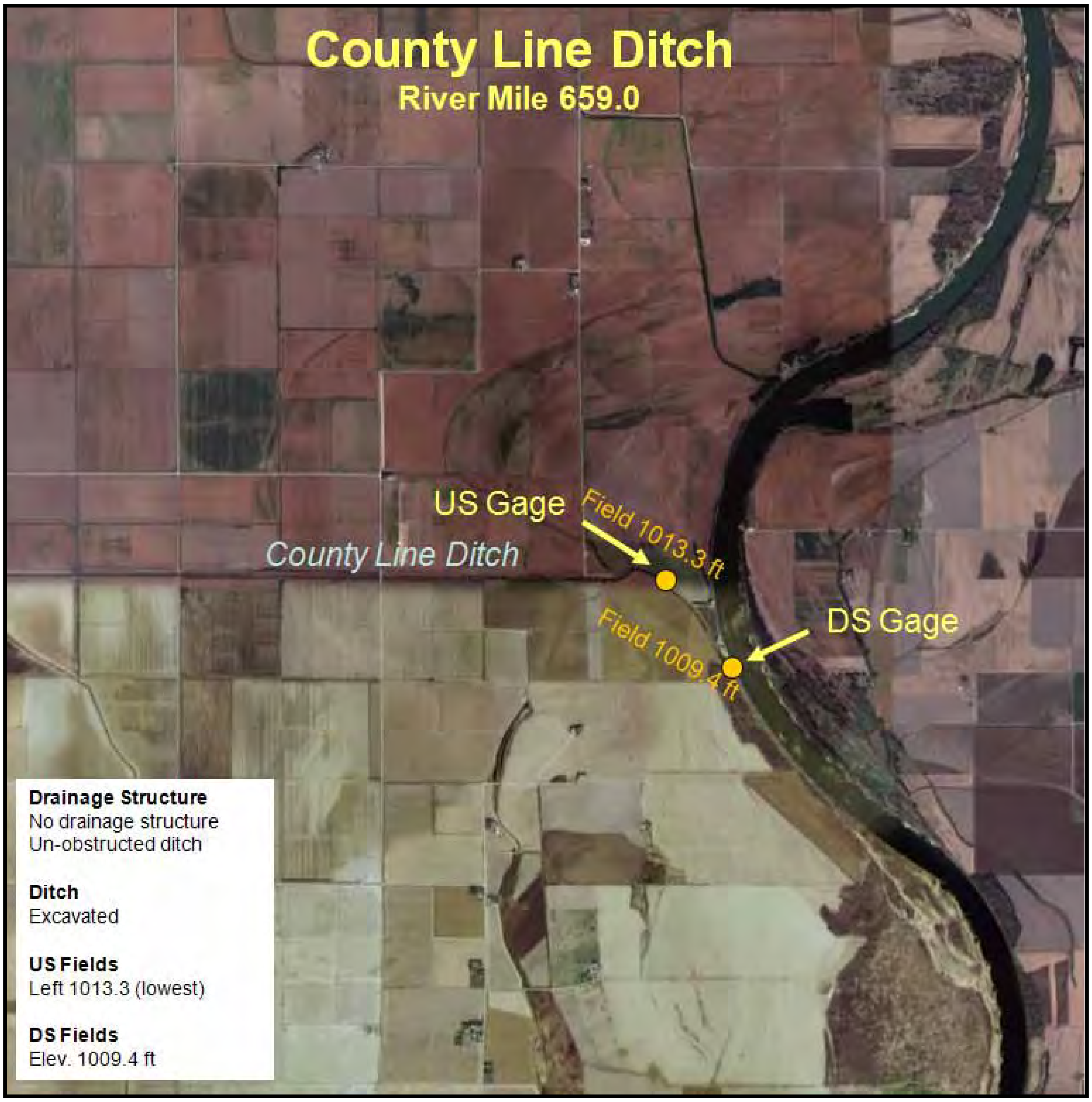

Figure 10.11.1 – County Line Ditch location

Figure 10.11.2 – County Line Ditch gages. US (left) and DS (right) supplemental gages.

Table 10.11.1 – County Line Ditch results

Spring Pulse from Gavins Point Dam	*May-09*	*Mar-08*
Created spring rise, ft	1.3	0.8
Estimated created spring rise flow, kcfs	5.4	2.8
Estimated MR flow at site, kcfs	34	24
% of MR flow	16	12

Outlet- and Inlet-flow thresholds

Invert elevations not available.

Table 10.11.2 – County Line Ditch NSR socioeconomic impacts

2009 Natural Spring Rise Impacts	*US Flooding*	*DS Flooding*
Elev, ft	1013.3	1009.4
Total impact duration, dy	no flooding	no flooding
Estimated MR flow at site, kcfs	-	-

2008 Natural Spring Rise Impacts	*US Flooding*	*DS Flooding*
Elev, ft	1013.3	1009.4
Total impact duration, dy	no flooding	no flooding
Estimated MR flow at site, kcfs	-	-

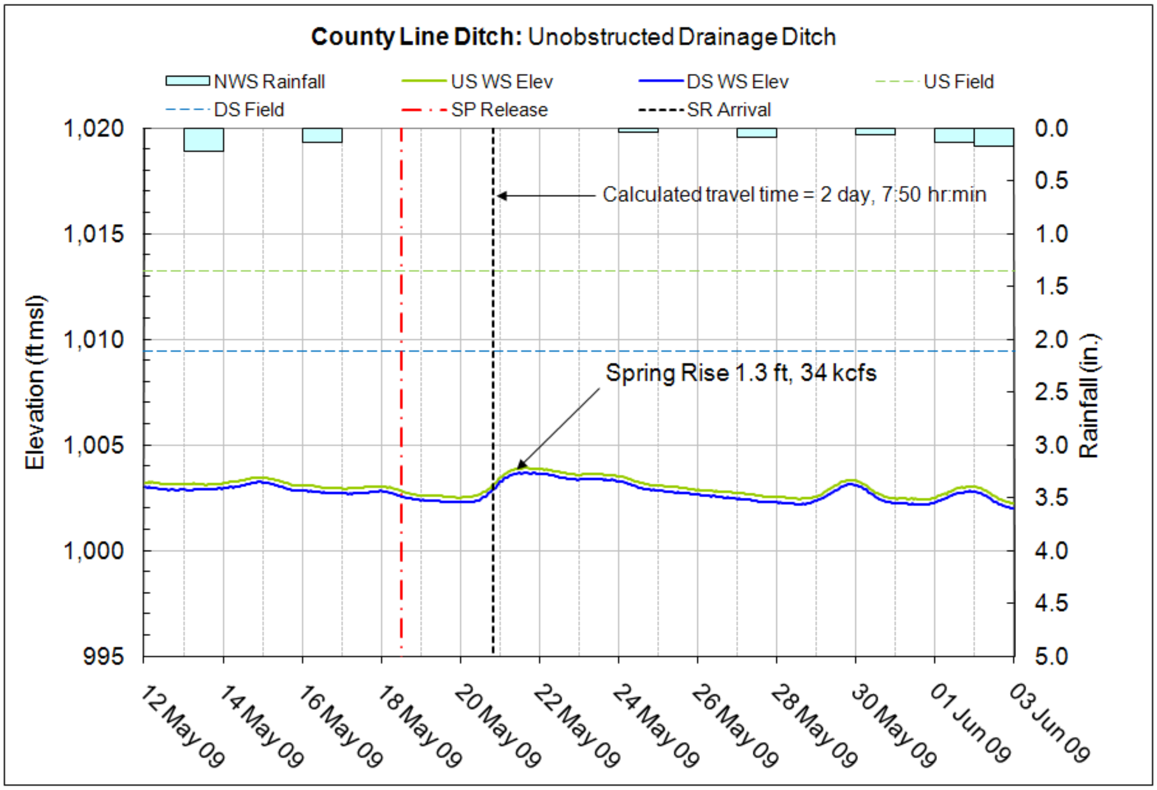

Figure 10.11.3 – Spring rise at County Line Ditch

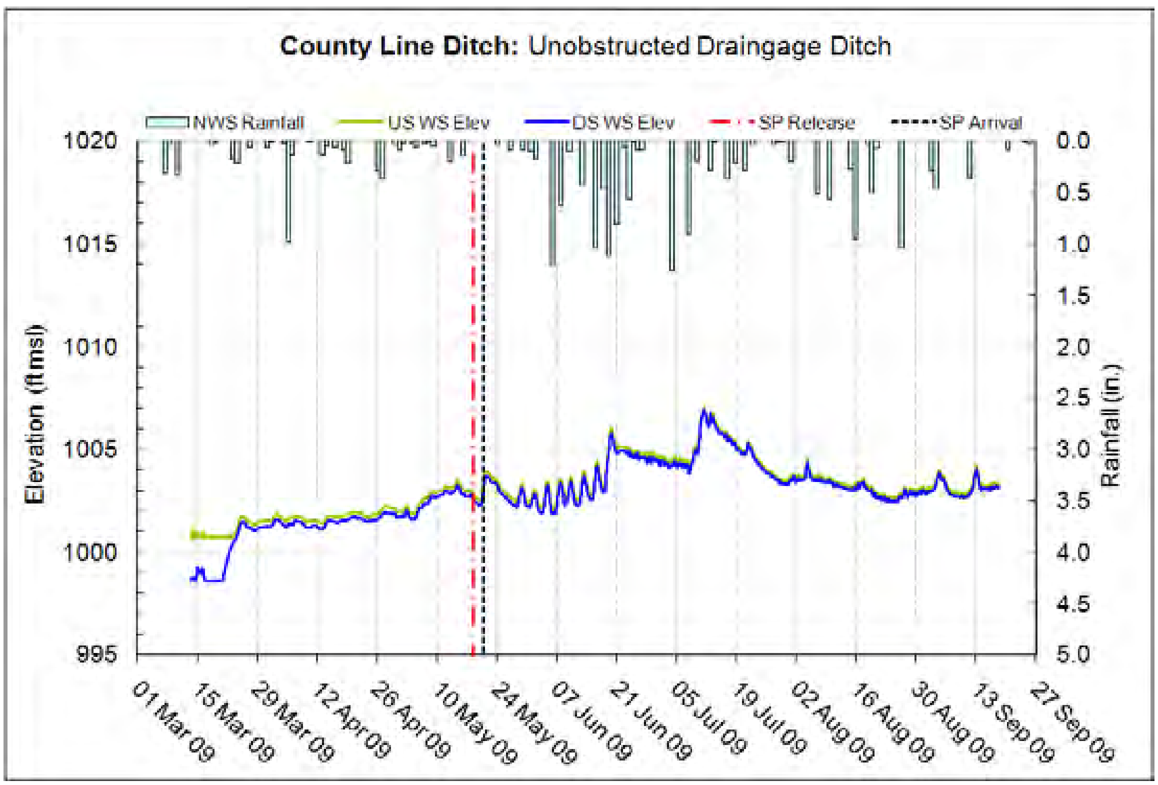

Figure 10.11.4 – Full monitoring record at County Line Ditch

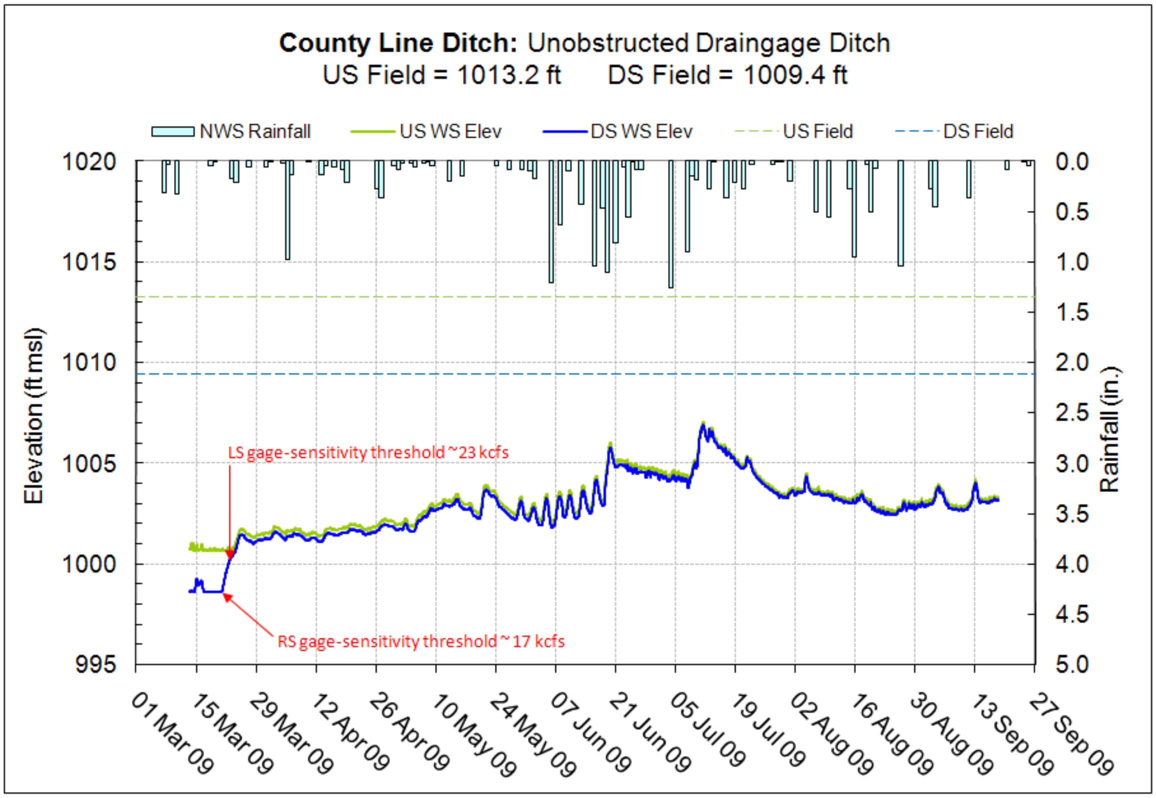

Figure 10.11.5 – Surveyed field elevations at County Line Ditch

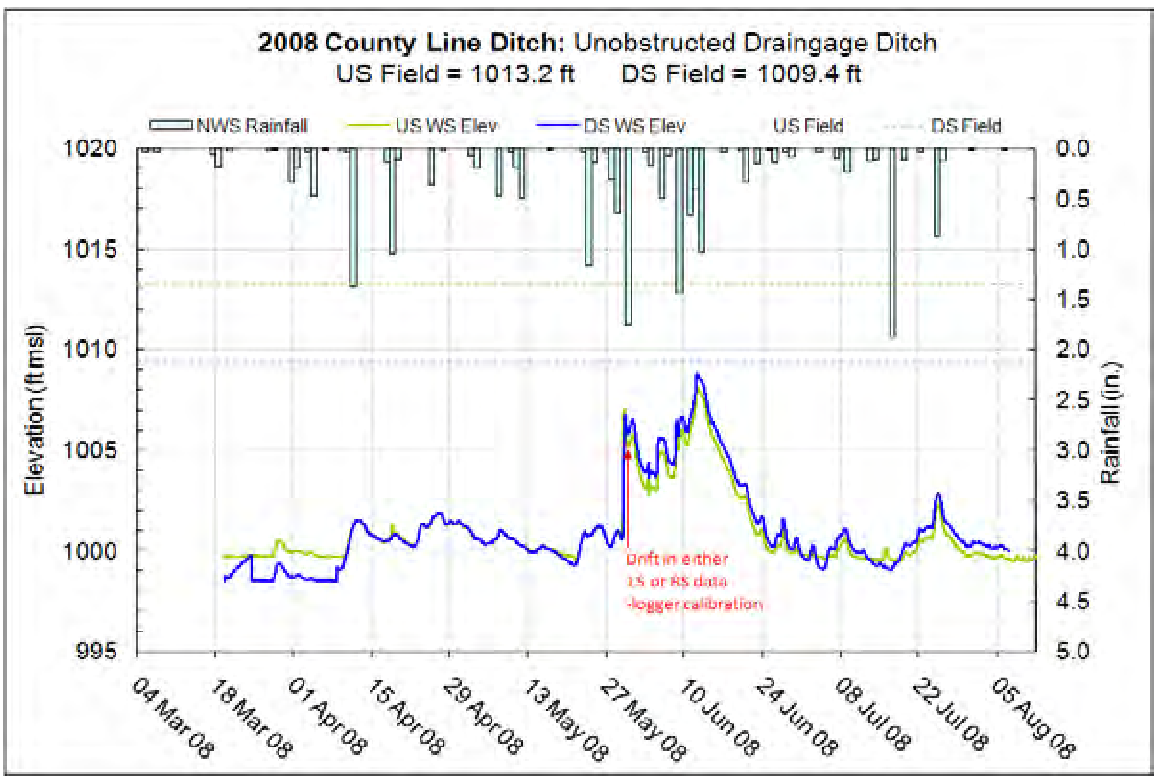

Figure 10.11.6 – Surveyed field elevations at County Line Ditch, 2008 record

10.12 California Bend

The California Bend drainage ditch originates northwest of Horseshoe Lake and flows south to the left bank of the Missouri River where it empties near river mile 650.6 into California Bend (Figure 6.12.1). A private levee with flap-gated drainage structures (Figure 6.12.2, center) crosses the ditch about 2,000 feet upstream of the ditch's mouth.

Two of the original three gages were monitored in 2009; the river gage was eliminated from the study. Landside and riverside gages are located on the landward and riverward sides of the private levee and monitor the effects of the spring rises on drainage through the levee culverts.

Field elevations were surveyed in March 2009. The surveyed LS left bank elevation was 1008.4 ft. The surveyed RS field and bank elevation was 1010.9 ft. Flows were estimated at the site by lagging the flow records of USGS Decatur and USGS Omaha to the site based on peaks and then interpolating flows based on river miles.

Results and Discussion

- Table 10.12.1 summarizes the results for the May 2009 and March 2008 created spring rises at California Bend. Table 10.122 summarizes the socioeconomic impacts produced by natural spring rises at the site in May 2009 and March 2008.
- Figure 10.12.3 shows the spring pulse release on May 18 and its arrival time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring pulse. The rise created by the spring pulse was 0.3 ft. Based on the attenuation analysis, the spring pulse accounts for 5.3 kcfs of the total 34 kcfs Missouri-River flow at this river mile, or 16% of the total flow. Only a portion of the created spring rise at the site was captured (0.3 ft) at the elevation of the data logger.
- Figure 10.12.4 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site shown.
- Inlet and outlet invert elevations at this site are not available and will need to be surveyed at a later date.
- Figure 10.12.5 shows the field elevations surveyed in 2009. This figure also shows the gage-sensitivity threshold for the RS gage. The Missouri River has to be at or above 34 kcfs to submerge the gage.

Conclusions

No socioeconomic impacts were created at this site by either the created spring pulse or the natural spring pulses of 2009. The rise created by the created spring rise at the RS gage was 0.3 ft. Based on the attenuation analysis, the spring pulse accounts for 5.3 kcfs of the total 34-kcfs Missouri-River flow at this river mile, or 16% of the total flow. Based on the 2008 attenuation analysis, the spring pulse accounted for 2.8 kcfs of the total 25-kcfs Missouri River flow, or 11% of the total flow. Inlet and outlet invert elevation flow thresholds could not be determined because the elevations are not known and will need to be surveyed.

Figure 10.12.1 – California Bend location

Figure 10.12.2 – California Bend site and gages. Culvert inlet with three CMPs and LS data logger (top left). Flap-gated outlets and RS gage (top right). Riverside drainage ditch (bottom left). Top of levee looking riverward (bottom right).

Table 10.12.1 – California Bend results

Spring Pulse from Gavins Point Dam	*May-09*	*Mar-08*
Created spring rise, ft	0.3	Not detected
Estimated created spring rise flow, kcfs	5.3	2.8
Estimated MR flow at site, kcfs	34	25
% of MR flow	16	11

Outlet- and Inlet-flow thresholds

Invert elevations not available.

Table 10.12.2 – California Bend NSR socioeconomic impacts

2009 Natural Spring Rise Impacts	*LS Flooding*	*RS Flooding*
Elev, ft	1008.4	1010.9
Total impact duration, dy	no flooding	no flooding
Estimated MR flow at site, kcfs	-	-

2008 Natural Spring Rise Impacts	*LS Flooding*	*RS Flooding*
Elev, ft	1008.4	1010.9
Impact duration, dy	no flooding	no flooding
Estimated MR flow at site, kcfs	-	-

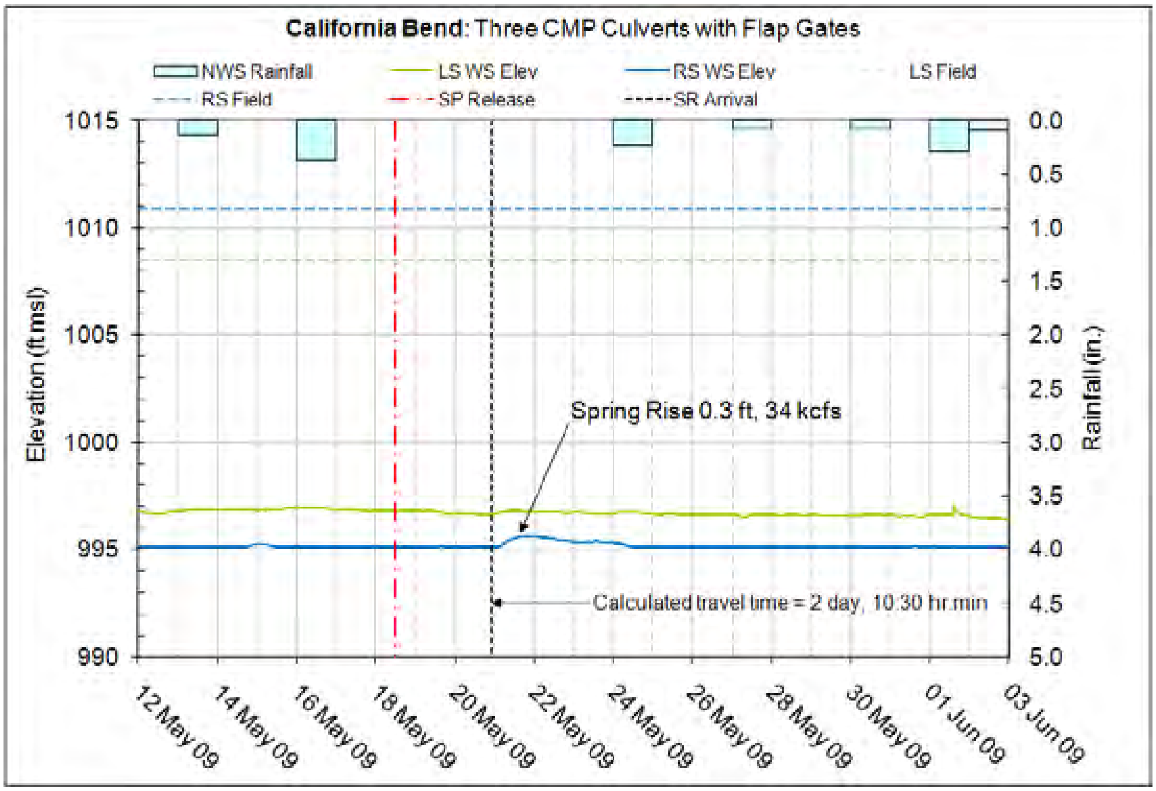

Figure 10.12.3 – Spring rise at California Bend

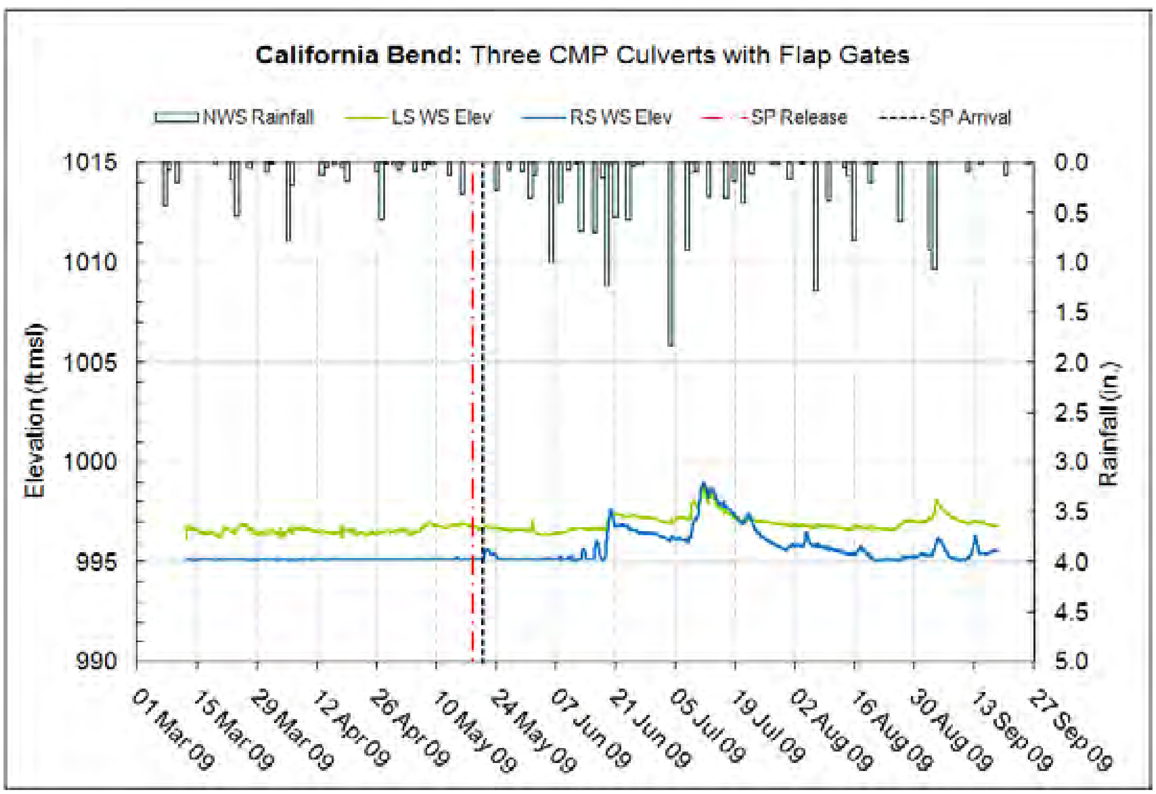

Figure 10.12.4 – Full monitoring record at California Bend

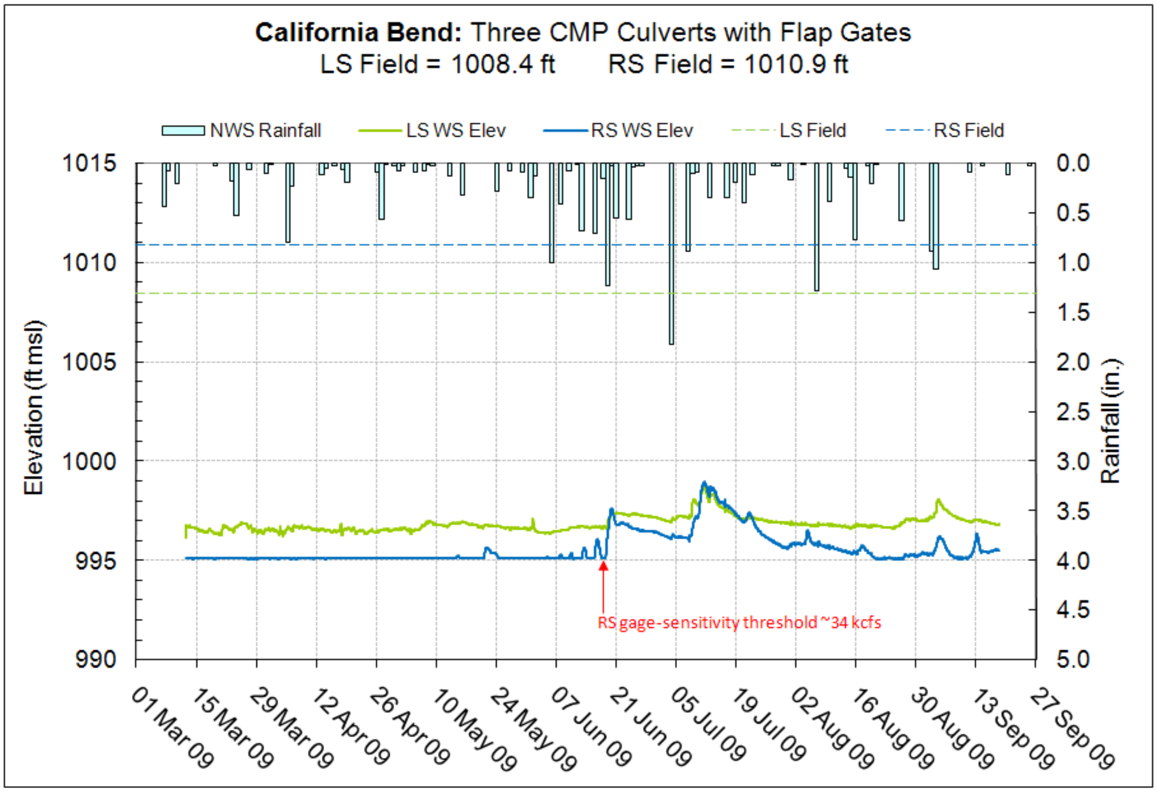

Figure 10.12.5 – Surveyed field elevations at California Bend

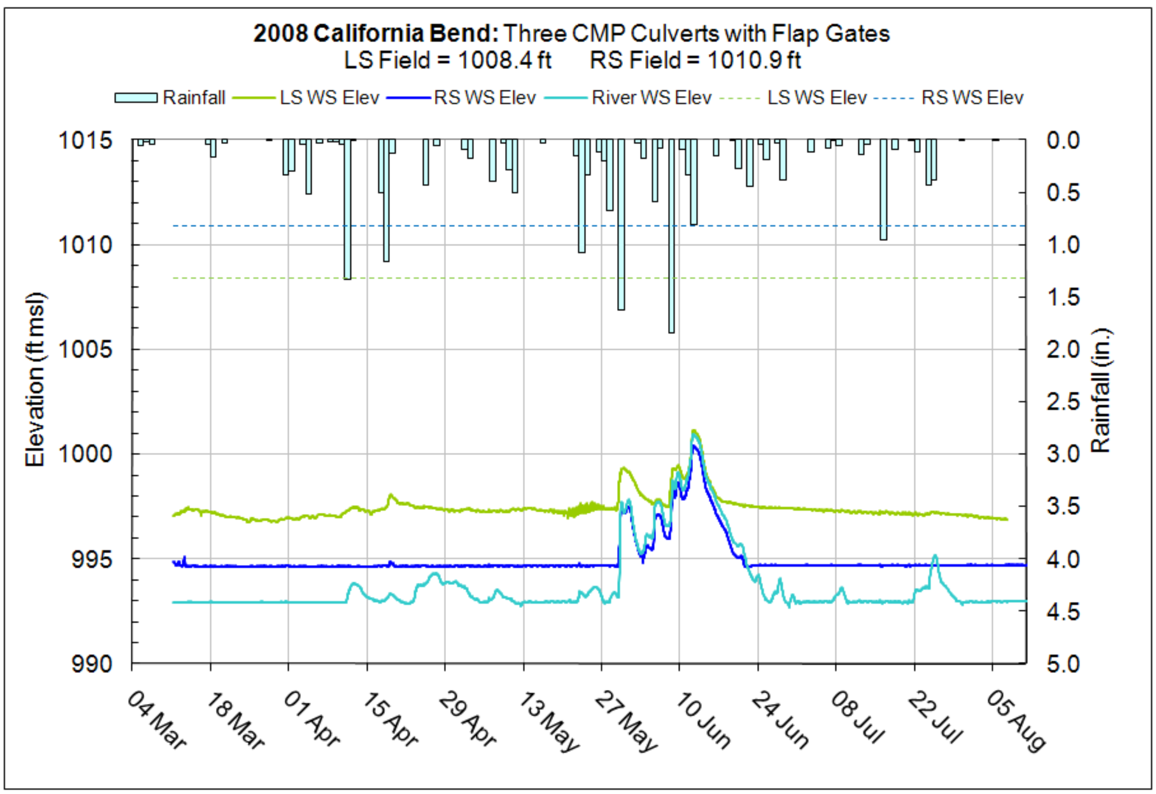

Figure 10.12.6 – Surveyed field elevations at California Bend, 2008 record

10.13 USACE Blair

The USACE Missouri River Blair gage is located at river mile 648.3 on the right bank of the Missouri River east of Blair, NE (Figure 10.13.1). Figure 10.13.2 shows the created spring rise produced by the spring pulse released from Gavins Point Dam. The created spring rise at this site was 1.4 ft. Figure 10.13.3 shows the full monitoring record with the travel time of the spring pulse noted.

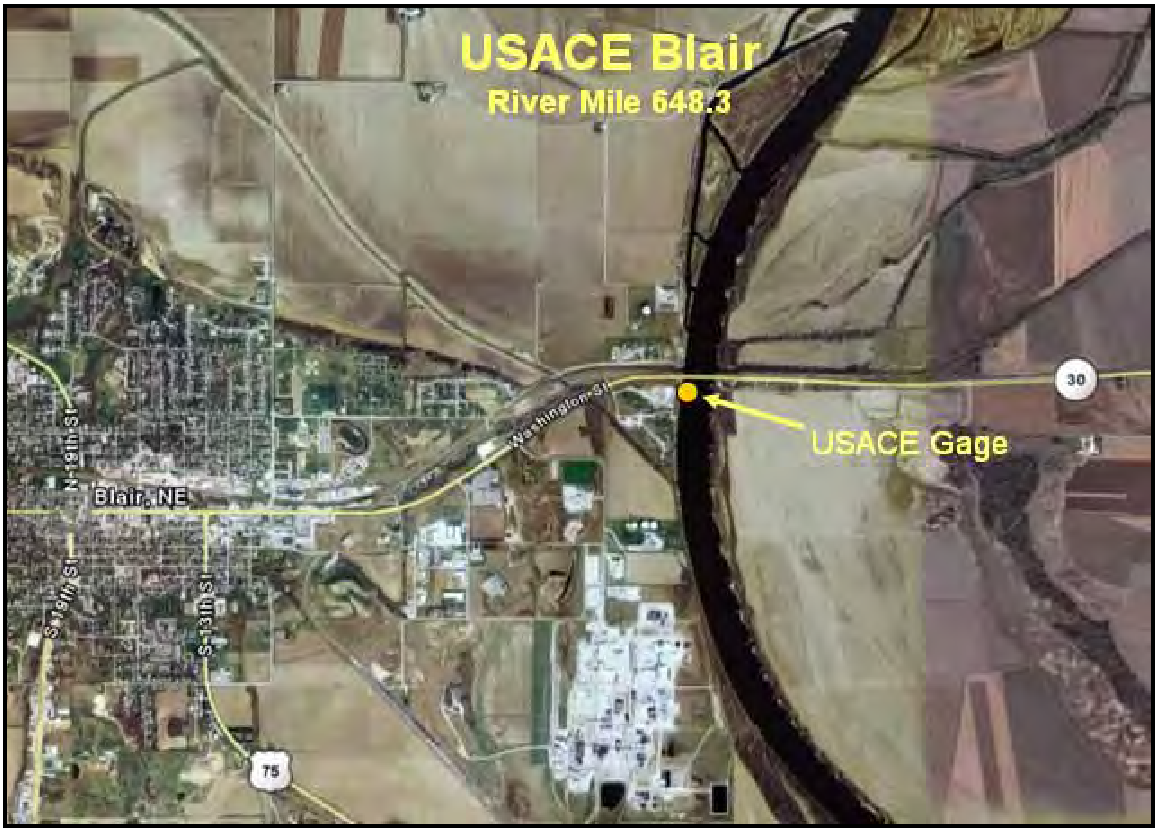

Figure 10.13.1 – USACE Blair location

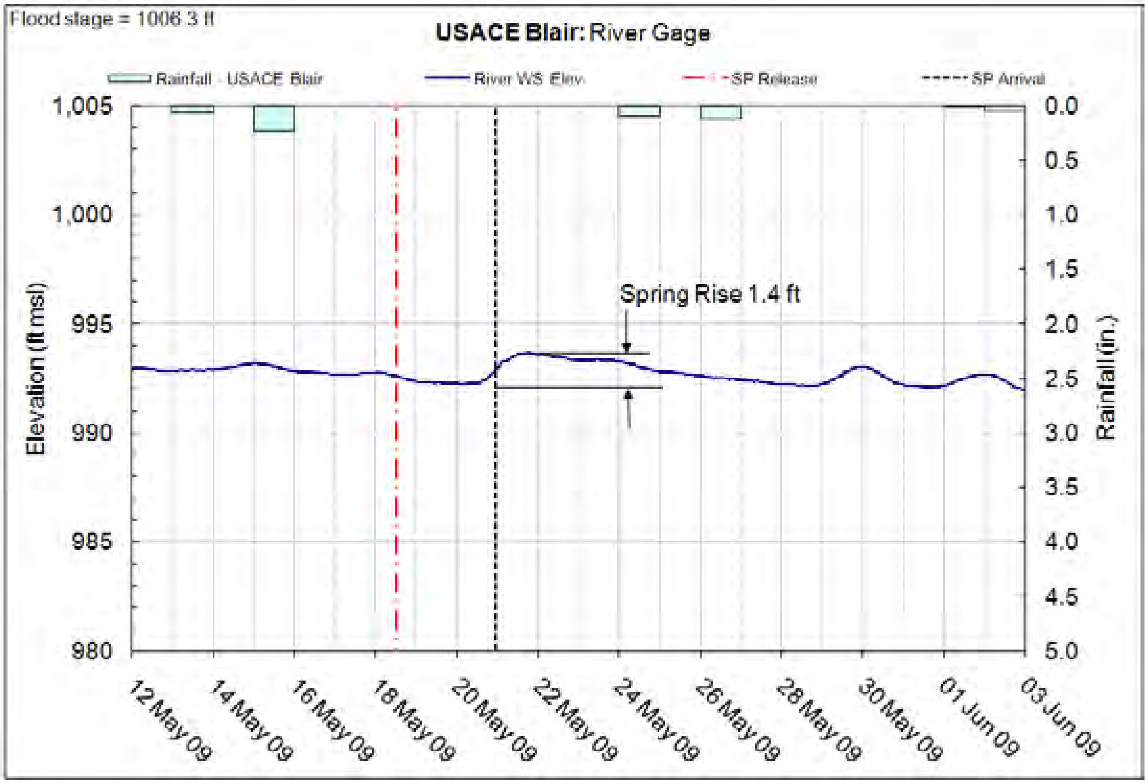

Figure 10.13.2 – Spring rise at USACE Blair

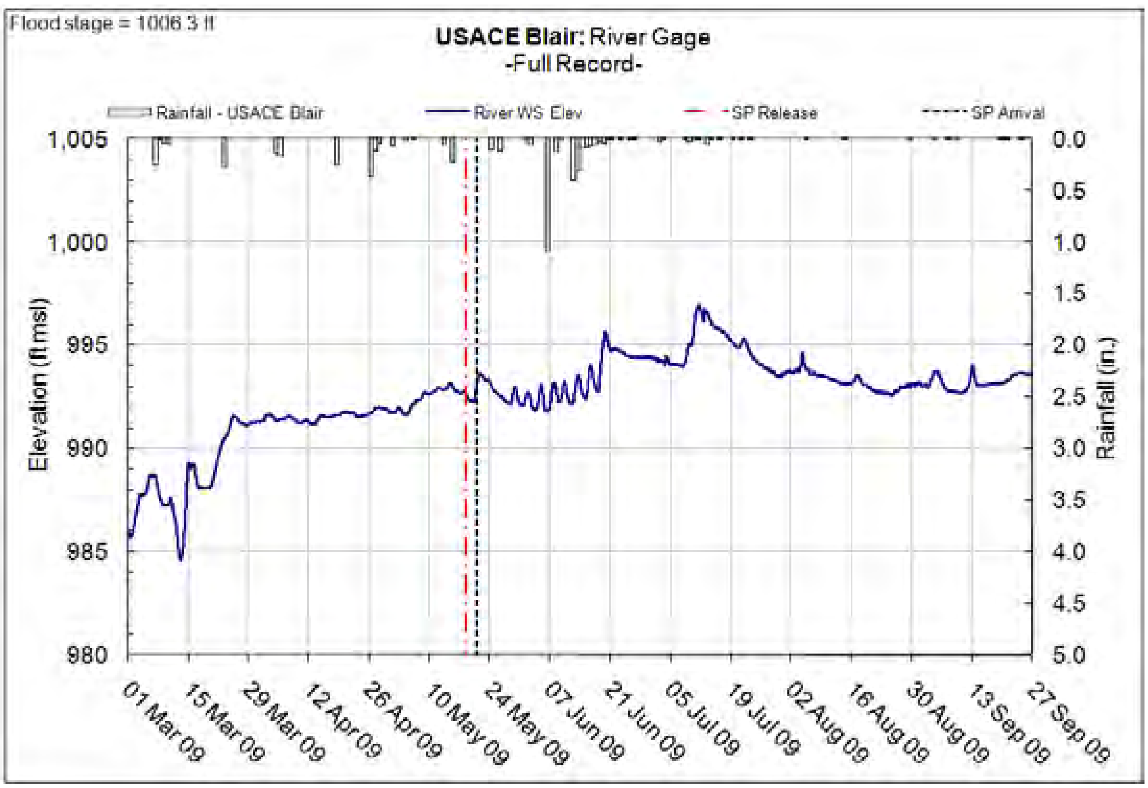

Figure 10.13.3 – Full monitoring record at USACE Blair

10.14 McIntosh Levee

The McIntosh Levee site (previously called McIntosh Ditch) is located on the left bank at river mile 637.1 just downstream from the headwaters of Boyer Chute and 6 miles southwest of Missouri Valley, IA (Figure 10.14.1). This site was selected because it is a location of known past drainage problems when the Missouri River stage is high. This site was monitored in 2006, 2008, and 2009. Two gage locations were selected to monitor the spring rises: a site upstream of a private levee and a site downstream of the private levee. The private levee is located approximately 2,000 feet upstream from the confluence of the ditch with the Missouri River. Both staff gages and data loggers were installed at both locations (Figure 10.14.2).

Field elevations were surveyed in March 2009. The elevation surveyed for the LS left bank field was 994.3 ft and the LS right bank field was 997.2 ft near the gage site. The elevation of the RS right bank field was 994.6 ft. The LS elevation used in the analysis and figures is 994.3 ft and the RS field elevation used is 994.6 ft. All elevations are in the NAVD 29 datum. Flows were estimated at the site by lagging the flow records of USGS Decatur and USGS Omaha to the site based on peaks and then interpolating flows based on river miles.

Results and Discussion

- Table 10.14.1 summarizes the results for the May 2009 and March 2008 created spring rises at McIntosh Levee. Table 10.14.2 summarizes the socioeconomic impacts produced by the natural spring rises at the site in May 2009 and March 2008.
- Figure 10.14.3 shows the spring pulse release on May 18 and its arrival time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring pulse. The rise created by the spring pulse and captured at the elevation of the gage was 0.8 ft. Based on the attenuation analysis, the spring pulse accounts for 5.2 kcfs of the total 35-kcfs Missouri-River flow at this river mile, or 15% of the total flow.
- Figure 10.14.4 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site shown.
- Figure 10.14.5 shows the surveyed field elevations. This figure also shows the gage-sensitivity threshold. The Missouri River has to be at or above 30 kcfs to submerge the RS gage at this site.
- Figure 10.14.6 shows the 2008 monitoring record with the field elevations surveyed in 2009. Based on the figure, no impacts occurred in 2008. However, personal communication with the landowner in September 2010 revealed that there was localized flooding in the RS fields downstream of the RS gage location and that crops had to be replanted. Based on this information, it is possible the RS gage may be moved downstream for the 2011 monitoring period or a second gage installed to capture impacts on the low-lying RS fields near the Missouri River.
- Tables 10.14.1 and 10.14.2 summarize the 2009 results and compares them with the results from 2008.

Conclusions

No socioeconomic impacts were created at this site by the created spring rise. The rise created by the created spring pulse at the RS gage was 0.8 ft. Based on the attenuation analysis, the spring pulse accounts for 5.2 kcfs of the total 35-kcfs Missouri-River flow at this river mile, or 15% of the total flow. Based on the attenuation analysis from 2008, the spring pulse accounted for 2.6 kcfs of the 25-kcfs Missouri-River flow at this river mile in March 2008,

or 10% of the total flow. Although no impacts were observed at the RS location in 2008, the landowner did report drainage problems due to the high May-June flows in 2008. It could not be determined if these impacts were due to overbank flooding or impeded drainage. To capture these impacts the RS gage may be moved downstream in 2011 or a third gage will be installed at the site.

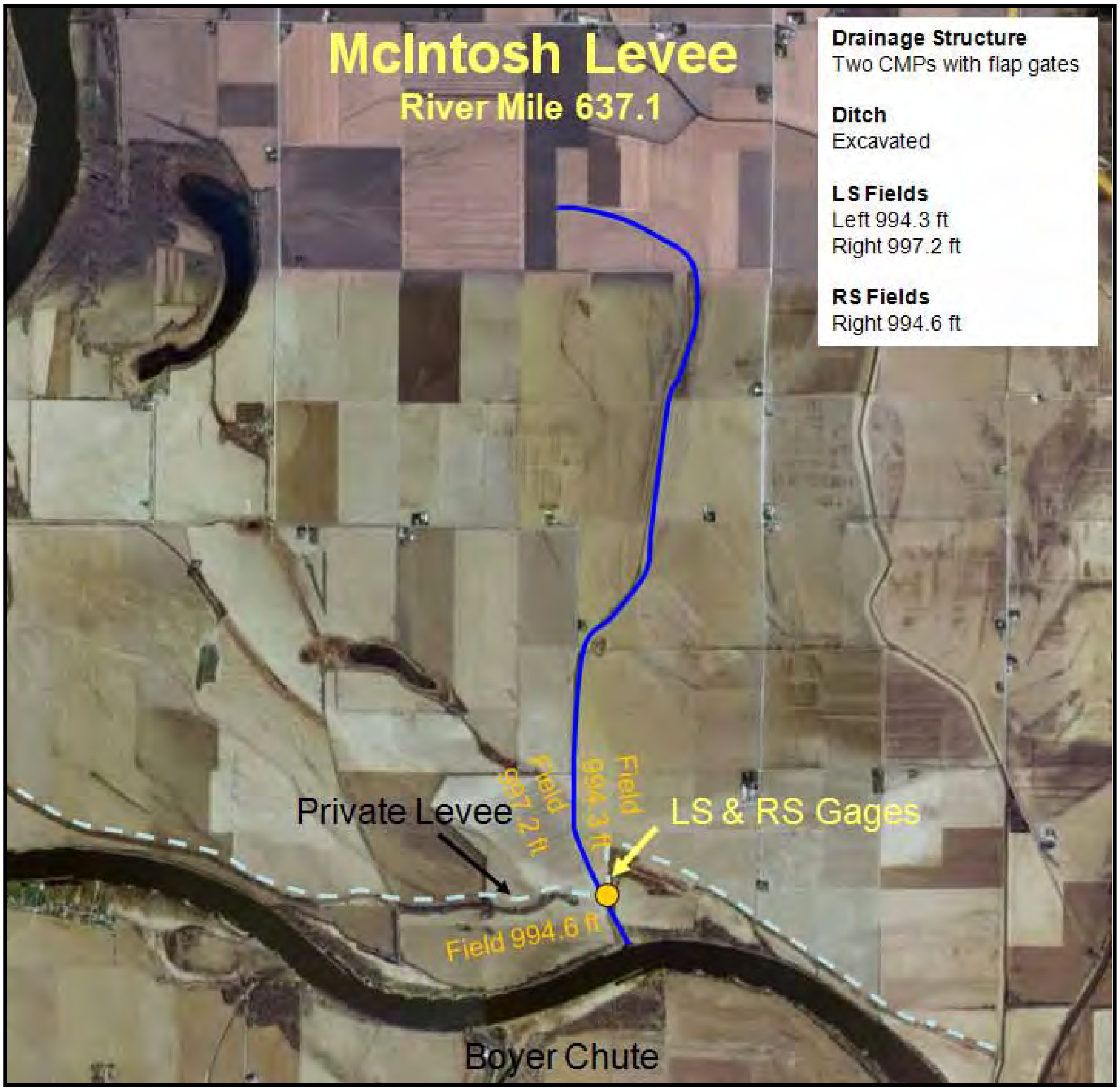

Figure 10.14.1 – McIntosh Levee location

 

Figure 10.14.2 – McIntosh Levee gages. Top of levee looking landward at fields and LS data logger (left). Top of levee looking riverward at RS data logger (right).

Table 10.14.1 – McIntosh Levee results

Spring Pulse from Gavins Point Dam

	May-09	***Mar-08***
Created spring rise, ft	0.8	n.a.
Estimated created spring rise flow, kcfs	5.2	2.6
Estimated MR flow at site, kcfs	35	25
% of MR flow	15	10

Outlet-flow Threshold

Invert elevations not available.

Table 10.14.2 – McIntosh Levee NSR socioeconomic impacts

2009 Natural Spring Rise Impacts

	LS Flooding	***RS Flooding***
Elev, ft	994.3	994.6
Total impact duration, dy	no flooding	no flooding
Estimated MR flow at site, kcfs	-	-
Flow at nearest US gage, kcfs	-	-
Nearest US gage	-	-

2008 Natural Spring Rise Impacts

	LS Flooding	***RS Flooding***
Elev, ft	994.3	994.6
Impact duration, dy	no flooding	no flooding
Estimated MR flow at site, kcfs	-	-
Flow at nearest US gage, kcfs	-	-
Nearest US gage	-	-

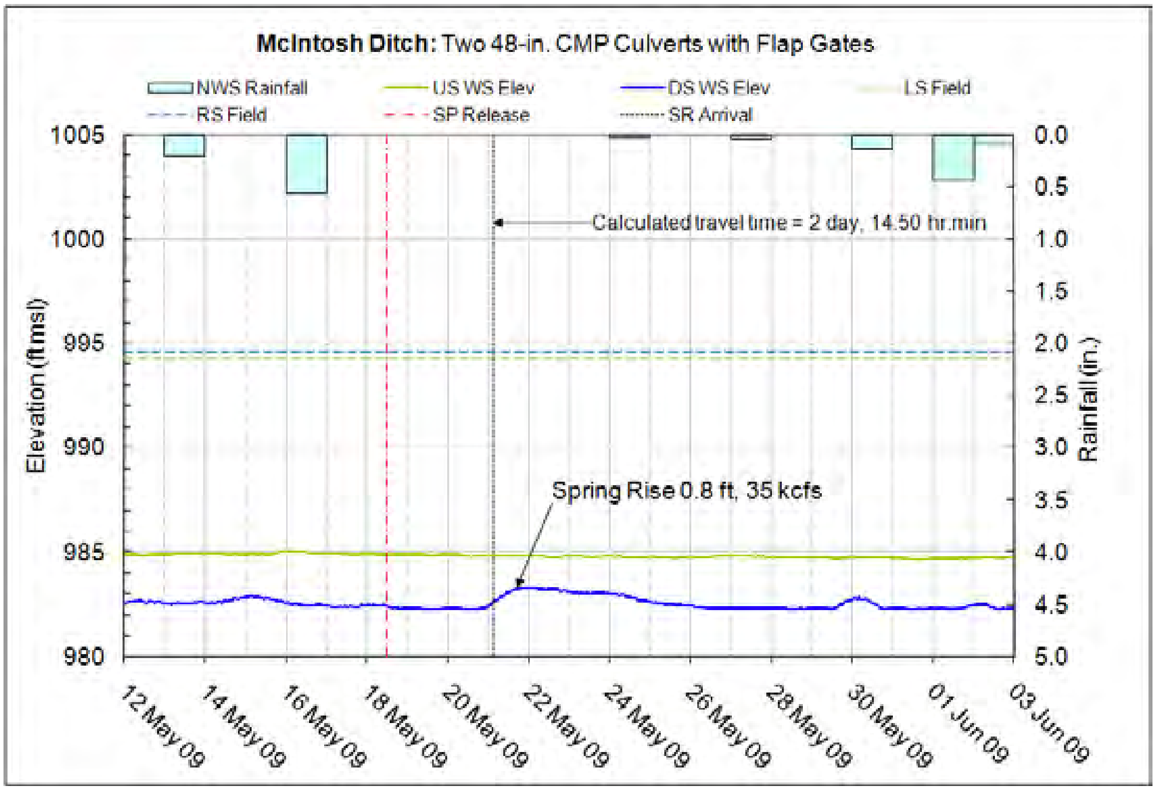

Figure 10.14.3 – Spring rise at McIntosh Levee

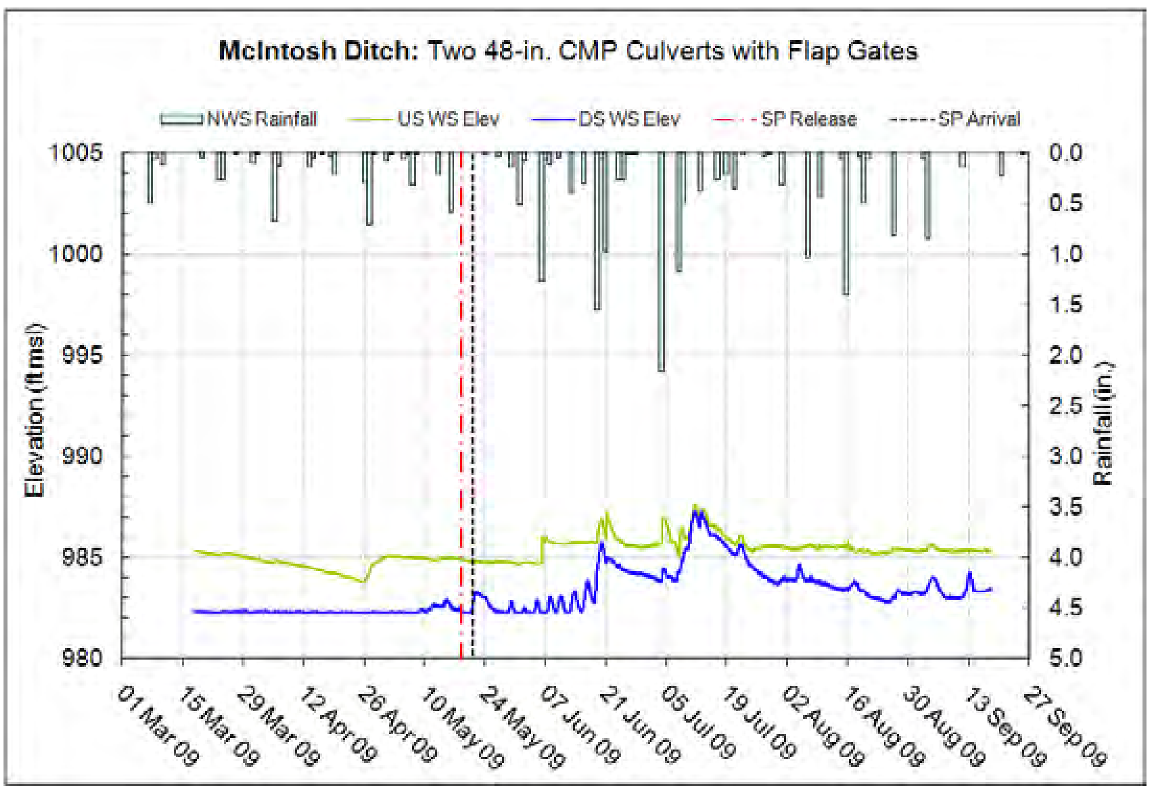

Figure 10.14.4 – Full monitoring record at McIntosh Levee

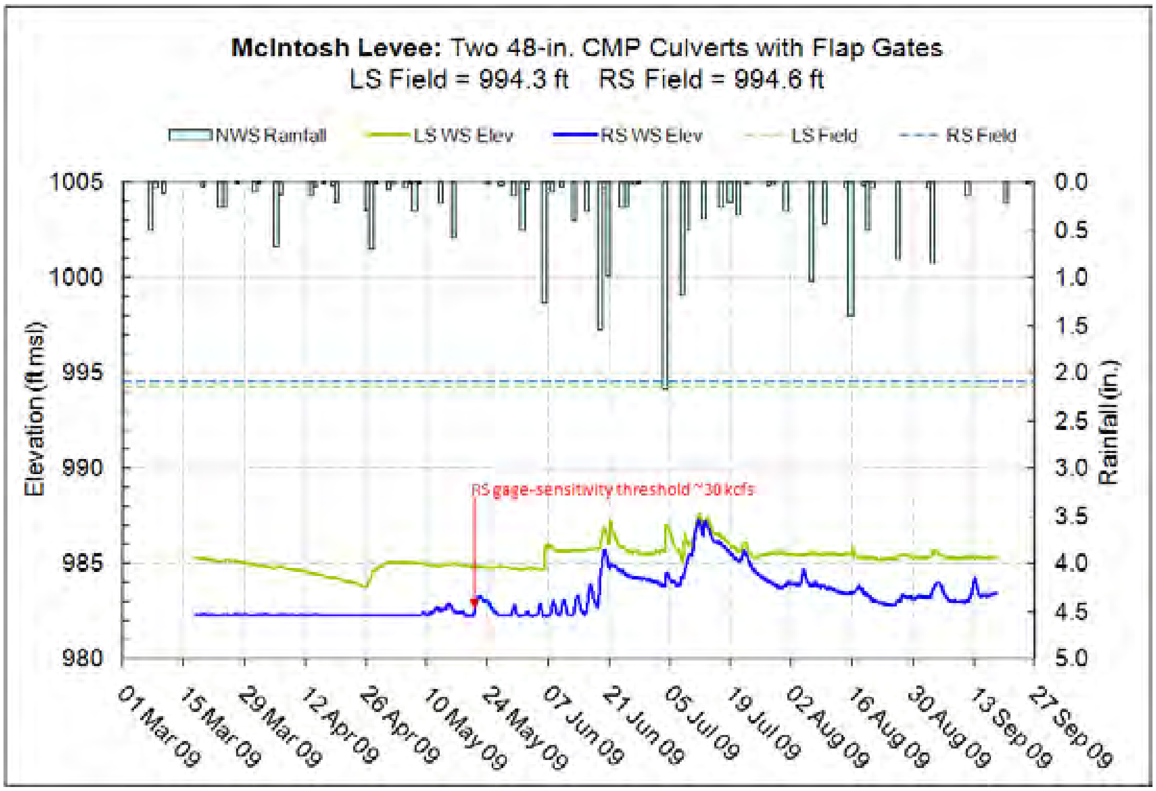

Figure 10.14.5 – Surveyed field elevations at McIntosh Levee

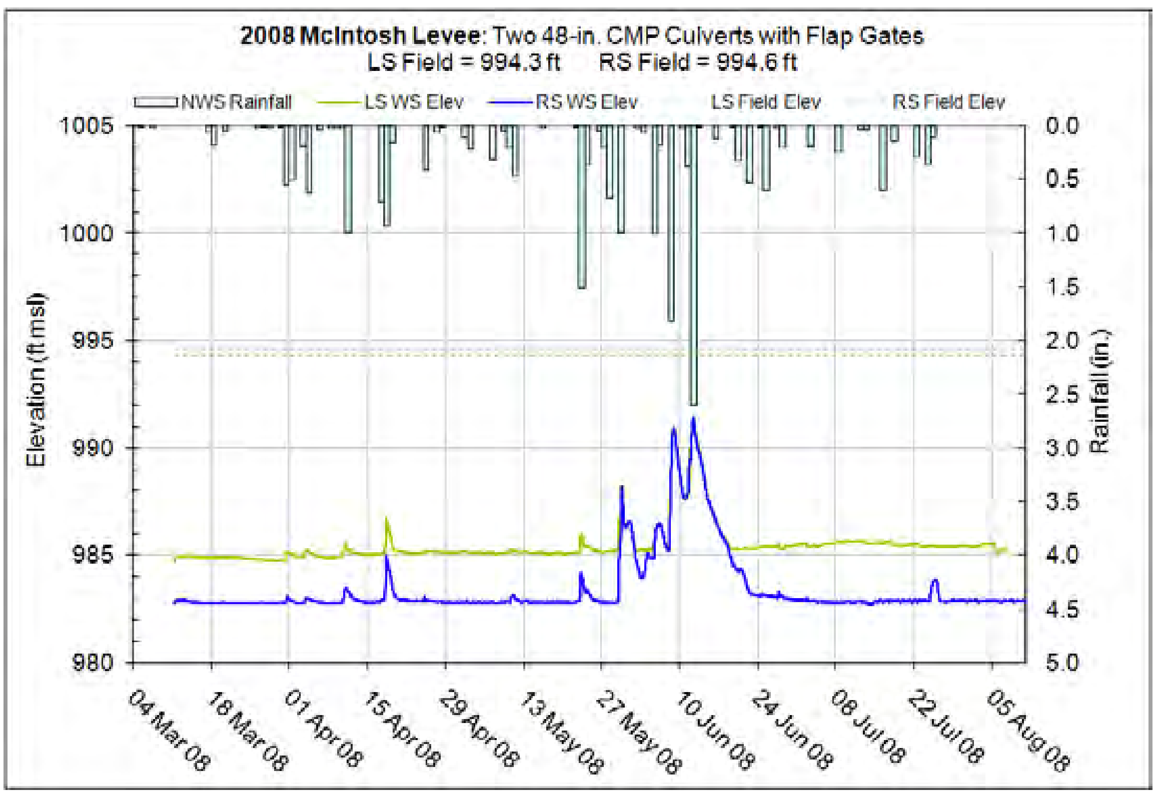

Figure 10.14.6 – Surveyed field elevations at McIntosh Levee, 2008 record

10.15 USGS Omaha

The USGS Missouri River Omaha gage is located on the right bank of the Missouri River at river mile 615.9 downstream of the I-480 Bridge between Omaha, NE and Council Bluffs, IA (Figure 10.15.1). Figure 10.15.2 shows the created spring rise produced by the spring pulse released from Gavins Point Dam. The created spring rise at this site was 1.4 ft. Figure 10.15.3 shows the full monitoring record with the travel time of the spring pulse noted.

Figure 10.15.1 – USGS Omaha location

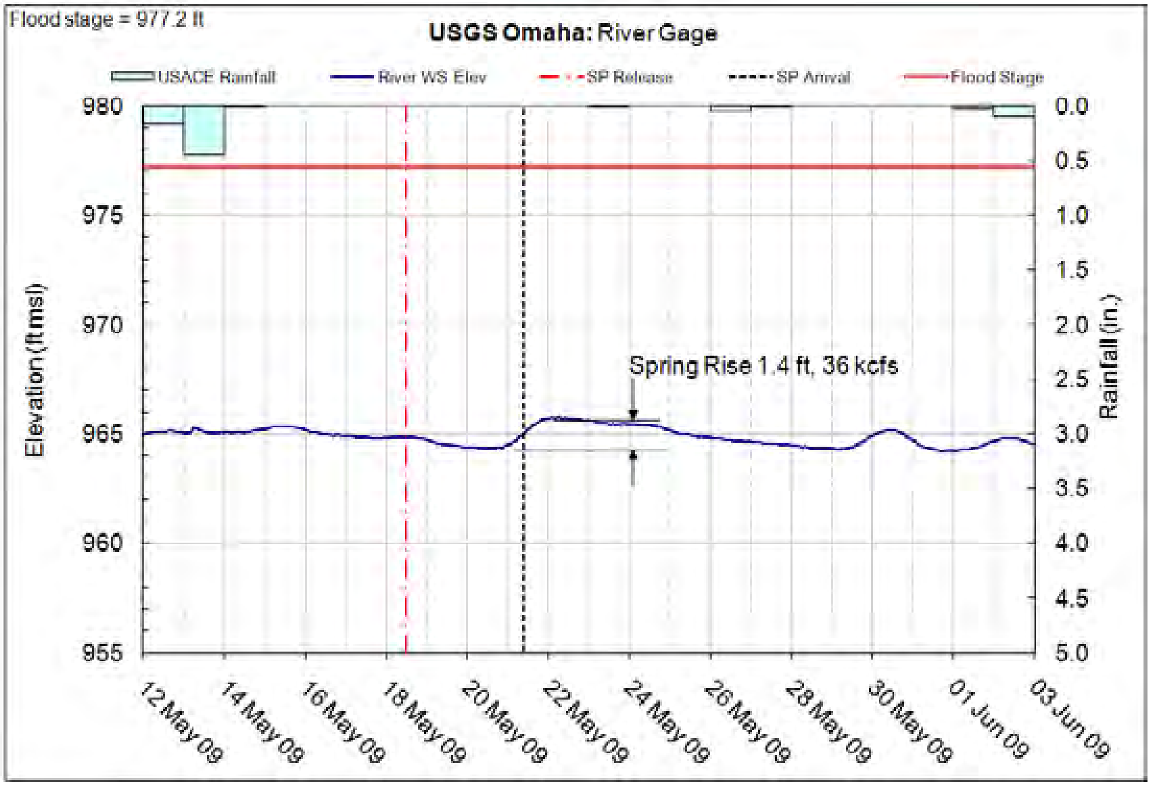

Figure 10.15.2 – Spring rise at USGS Omaha

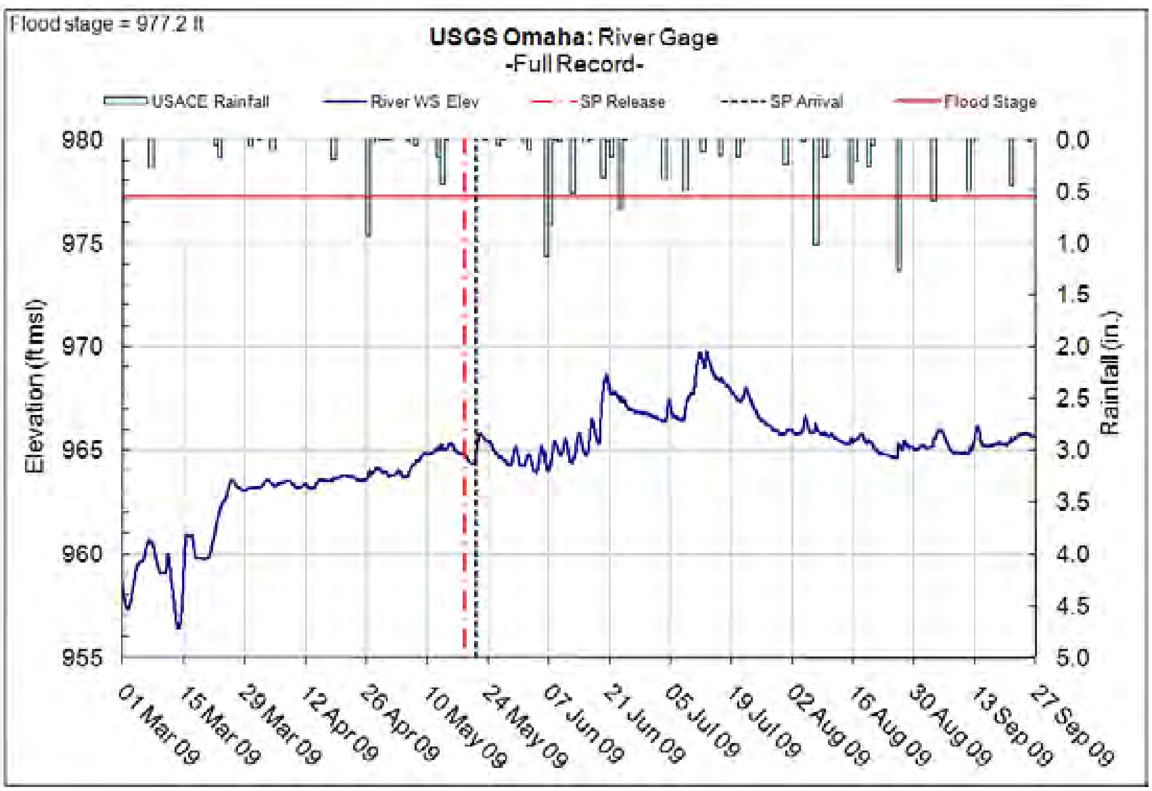

Figure 10.15.3 – Full monitoring record at USGS Omaha

10.16 La Platte

The La Platte supplemental gage is located approximately 0.5 mile upstream of the Platte River confluence with the Missouri River, south of the city of Bellevue, NE (Figure 10.16.1). Both a staff gage and a data logger were installed at this site near river mile 596.7 (Figure 10.16.2). This site was added in March 2008 to capture the effects of the Platte River on the Missouri River and the created spring rise upstream of the confluence. The gage was relocated downstream about 100 ft to a more sheltered location after being washed out during the high flows of June 2008. Flows were estimated at the site by lagging the flow records of USGS Omaha to the site.

Results and Discussion

- Table 10.16.1 summarizes the results for the May 2009 and March 2008 created spring rises at La Platte.
- Figure 10.16.3 shows the spring pulse release and its arrival time to the site. The rise created by the May spring pulse was 0.7 ft. Based on the attenuation analysis, the spring pulse accounts for 4.6 kcfs of the total 35-kcfs Missouri-River flow at this river mile, or 13% of the total flow.
- Figure 10.16.4 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site shown.

Conclusions

Based on the attenuation analysis, the spring pulse accounts for 4.6 kcfs of the total 35-kcfs Missouri-River flow at this river mile, or 13% of the total flow in 2009. Based on the attenuation analysis from 2008, the spring pulse accounted for 2.2 kcfs of the total 29-kcfs Missouri-River flow at this river mile, or 7.5% of the total flow.

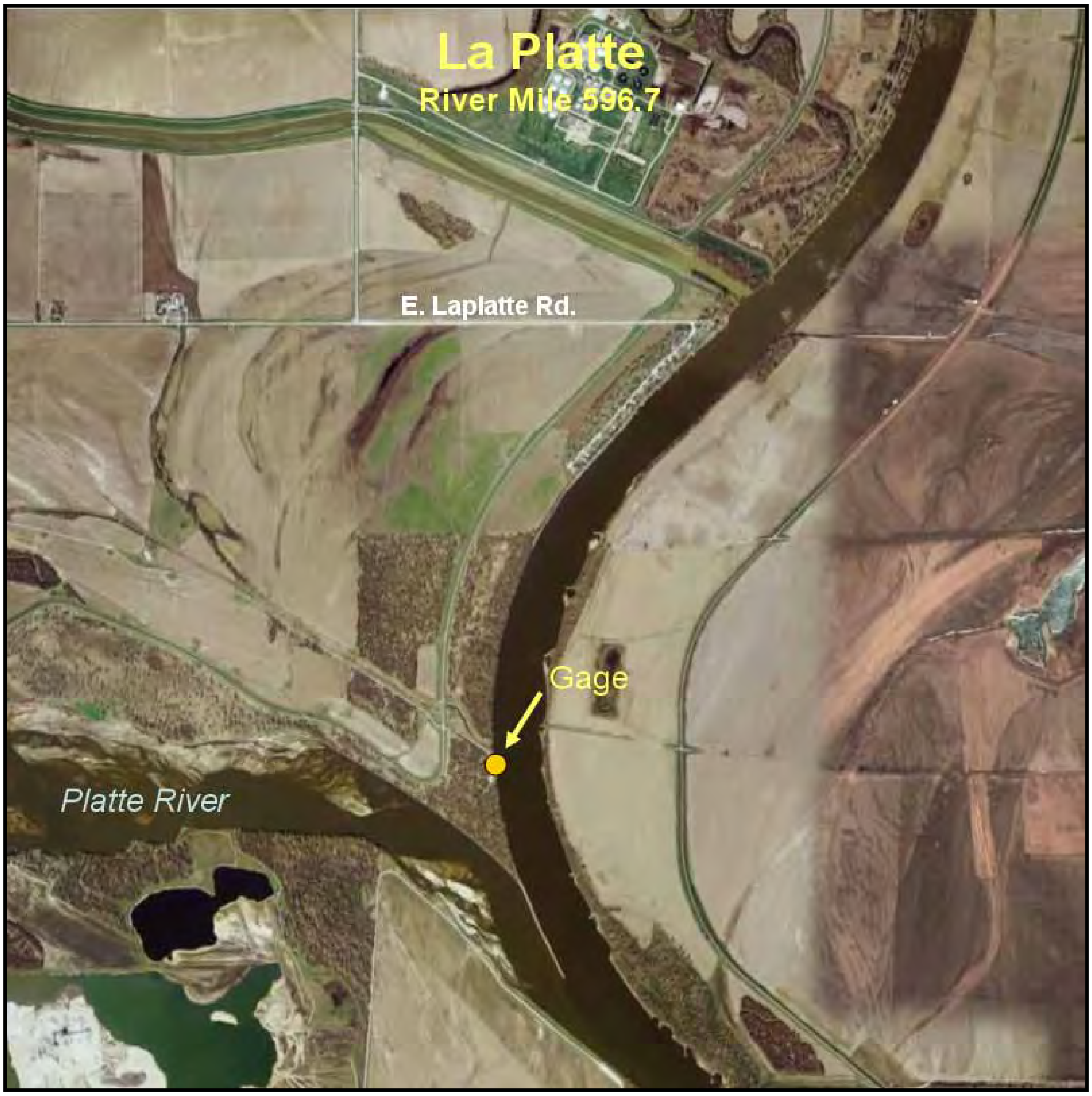

Figure 10.16.1 – La Platte gage location

Figure 10.16.2 – La Platte gages

Table 10.16.1 – La Platte results

Spring Pulse from Gavins Point Dam

	May-09	*Mar-08*
Created spring rise, ft	0.7	0.52
Estimated created spring rise flow, kcfs	4.6	2.2
Estimated MR flow at site, kcfs	35	29
% of MR flow	13	7.5

Impacts

River gage; no socioeconomic impacts documented.

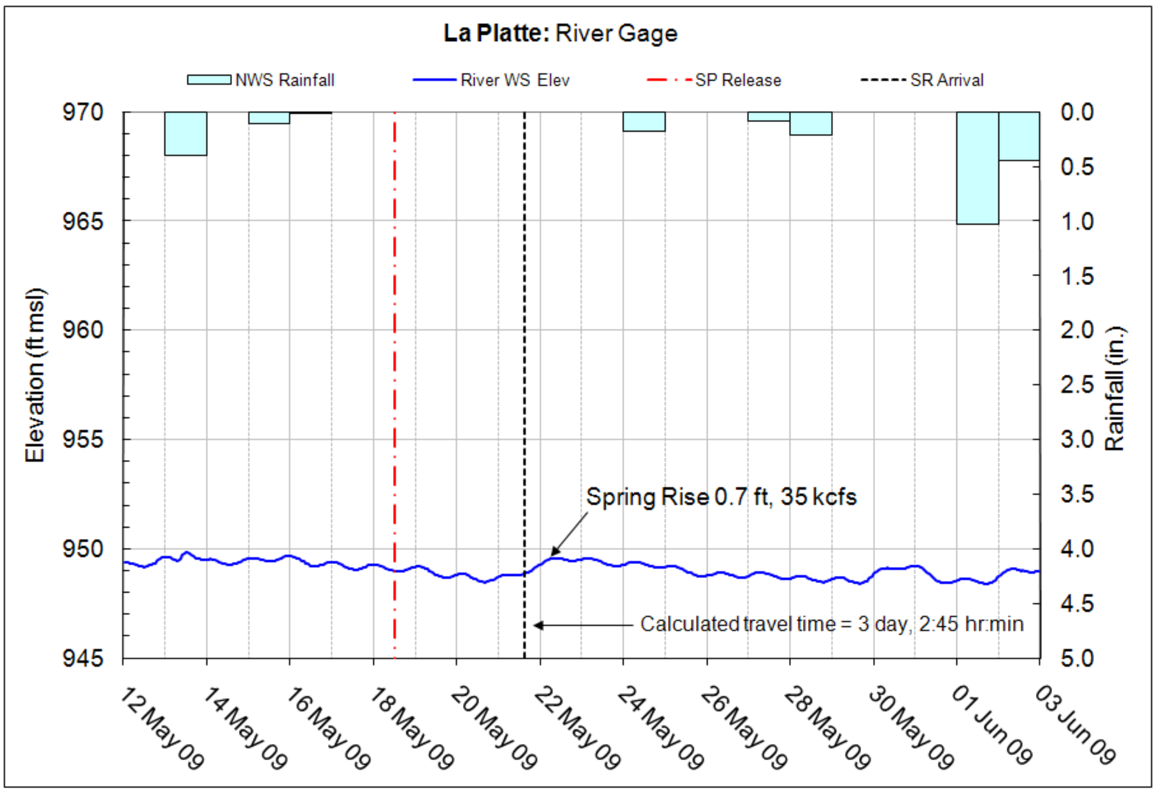

Figure 10.16.3 – Spring rise at La Platte

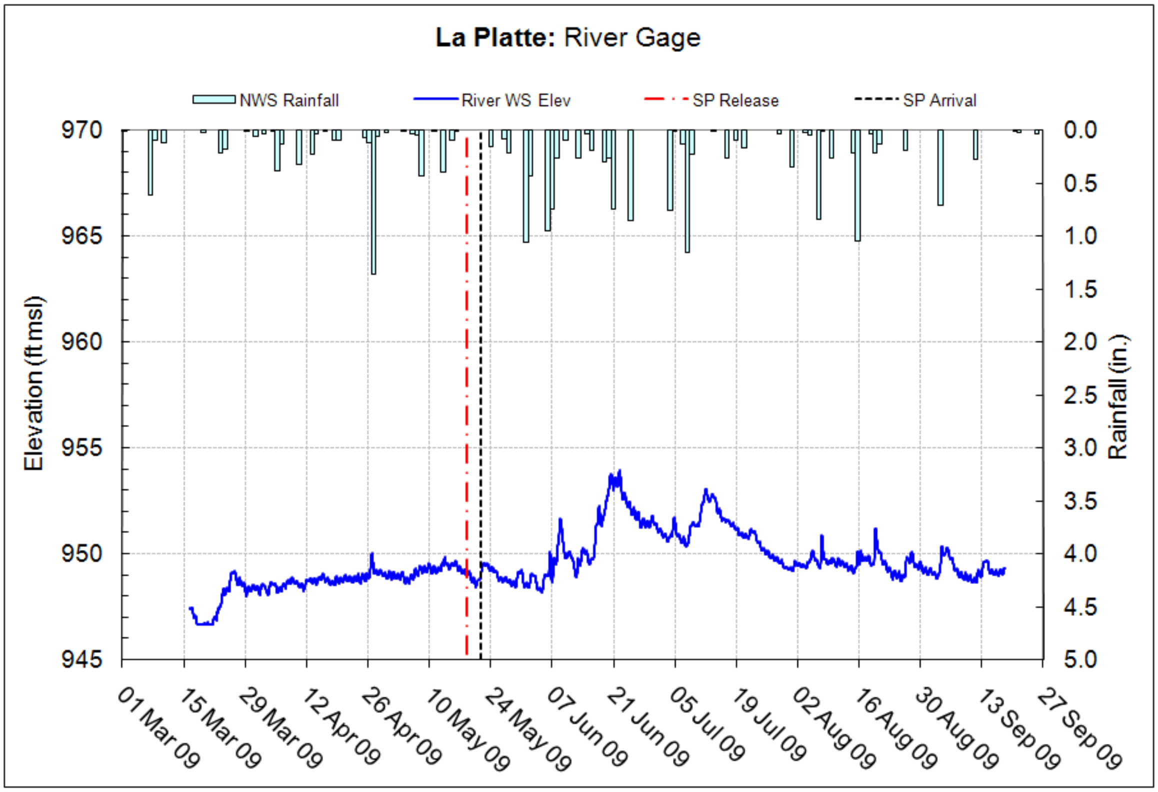

Figure 10.16.4 – Full monitoring record at Platte

10.17 USACE Plattsmouth

The USACE Missouri River Plattsmouth gage is located east of Plattsmouth, NE at river mile 591.5 (Figure 10.17.1). Figure 10.17.2 shows the created spring rise produced by the spring pulse released from Gavins Point Dam. The created spring rise at this site was approximately 0.7 ft. Figure 10.17.3 shows the full monitoring record with the travel time of the spring pulse noted. Figure 10.17.3 shows flows went above flood stage once during the full monitoring record.

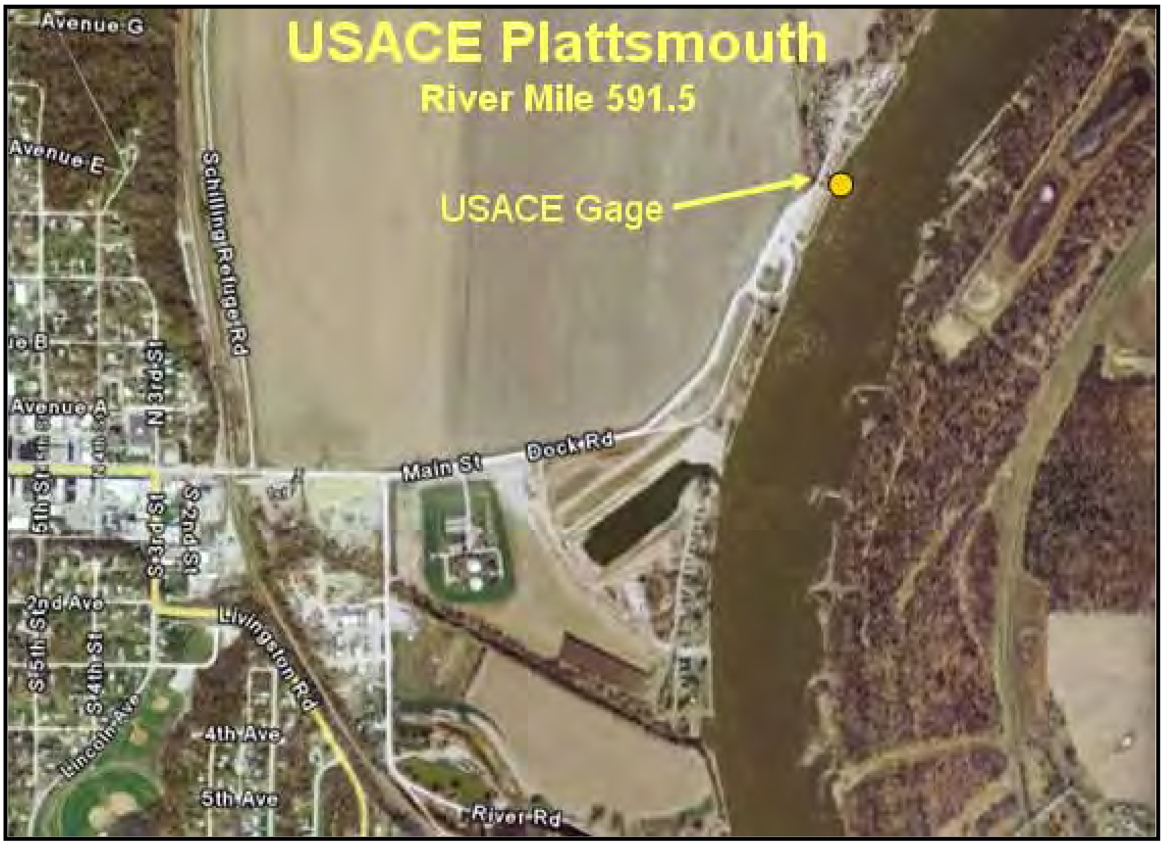

Figure 10.17.1 – USACE Plattsmouth location

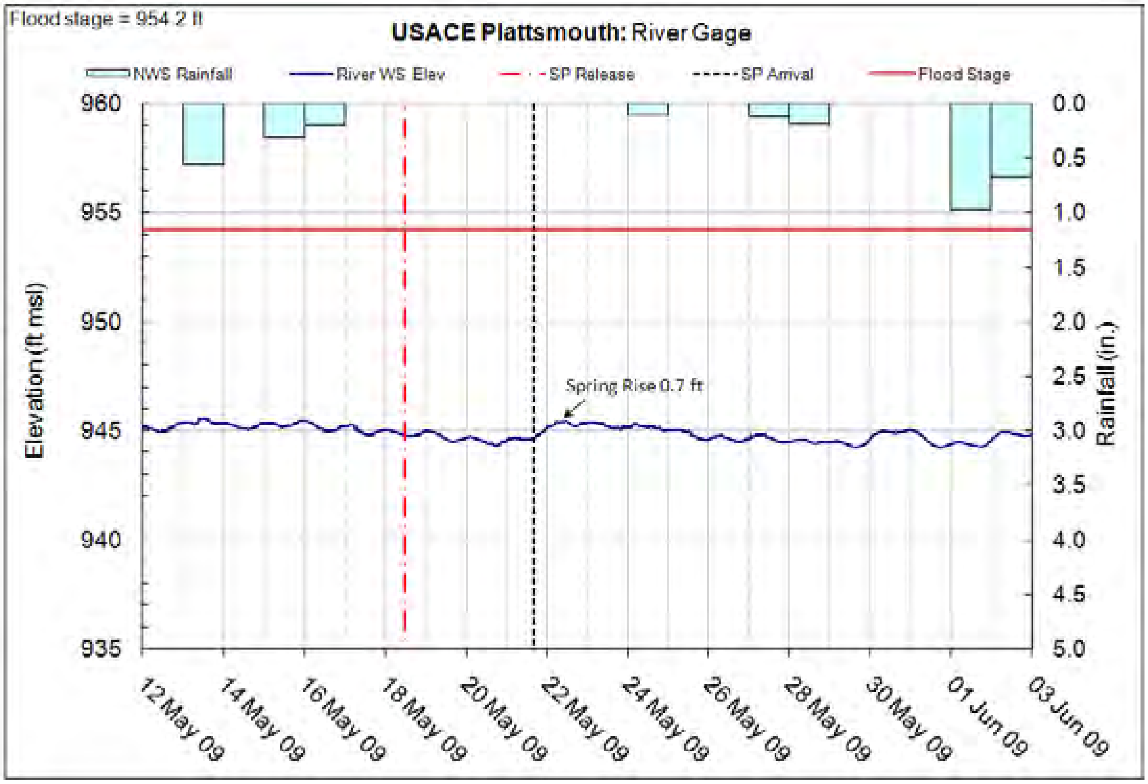

Figure 10.17.2 – Spring rise at Plattsmouth

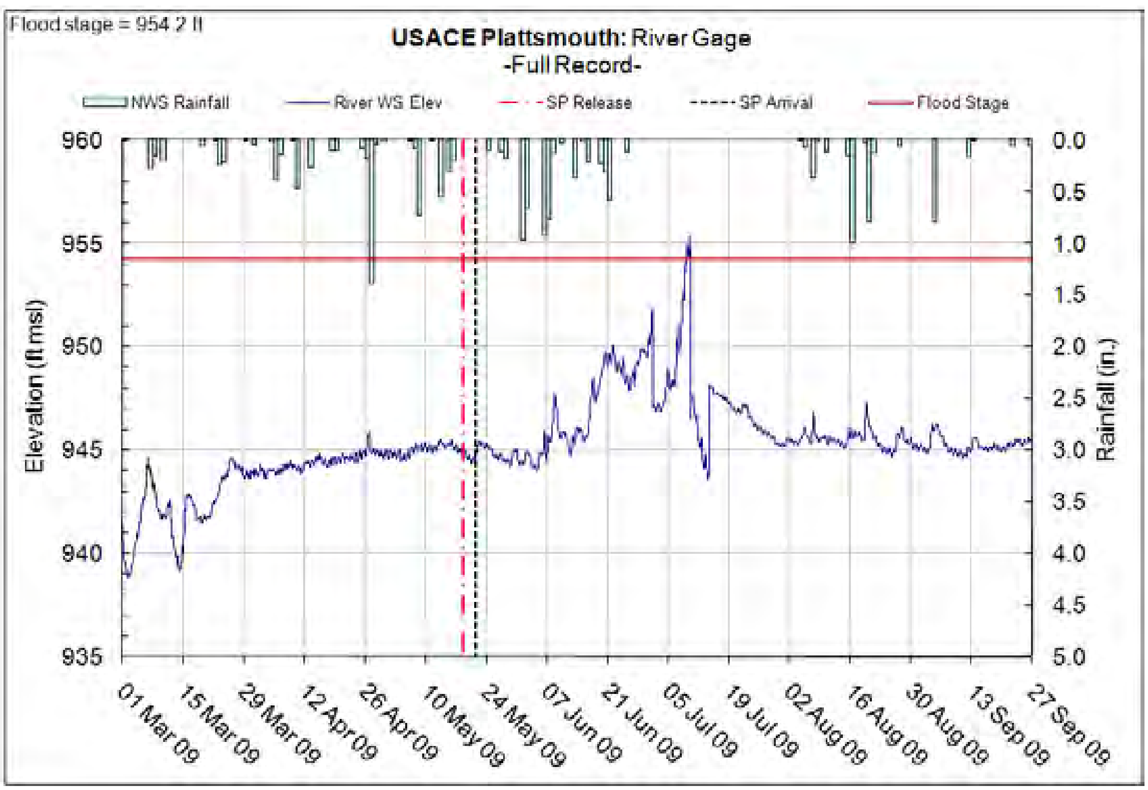

Figure 10.17.3 – Full monitoring record at USACE Plattsmouth

10.18 Lake Wa Con Da

The Lake Wa Con Da supplemental gage is located east of the northern-most tip of Lake Wa Con Da (Figure 10.18.1) approximately 5 miles northwest of the town of Union in Cass County, NE. This site is located at river mile 577.5 and was added to monitor the effects of created and natural spring rises downstream from the Missouri River confluence with the Platte River. This supplemental site consisted of both a staff gage and a data logger (Figure 10.18.2). The location of the gage is the same as last year. Flows were estimated at the site by lagging the flow records of USGS Nebraska City to the site.

Results and Discussion

- Table 10.18.1 summarizes the results for the May 2009 and March 2008 created spring rises at Lake Wa Con Da.
- Figure 10.18.3 shows the spring pulse release and its arrival time to the site. The rise created by the May spring pulse was 0.6 ft. Based on the attenuation analysis, the spring pulse accounts for 4.4 kcfs of the total 40-kcfs Missouri-River flow at this river mile, or 11% of the total flow.
- Figure 10.18.4 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site shown.

Conclusions

Based on the attenuation analysis, the spring pulse accounts for 4.4 kcfs of the total 40-kcfs Missouri-River flow at this river mile, or 11% of the total flow.

Table 10.18.1 – Lake Wa Con Da results

Spring Pulse from Gavins Point Dam	***May-09***	***Mar-08***
Created spring rise, ft	0.6	0.2
Estimated created spring rise flow, kcfs	4.4	2.0
Estimated MR flow at site, kcfs	40	30
% of MR flow	11	6.5

Impacts

River gage; no socioeconomic impacts documented.

Figure 10.18.1 – Lake Wa Con Da location



Figure 10.18.2 – Lake Wa Con Da site and gages

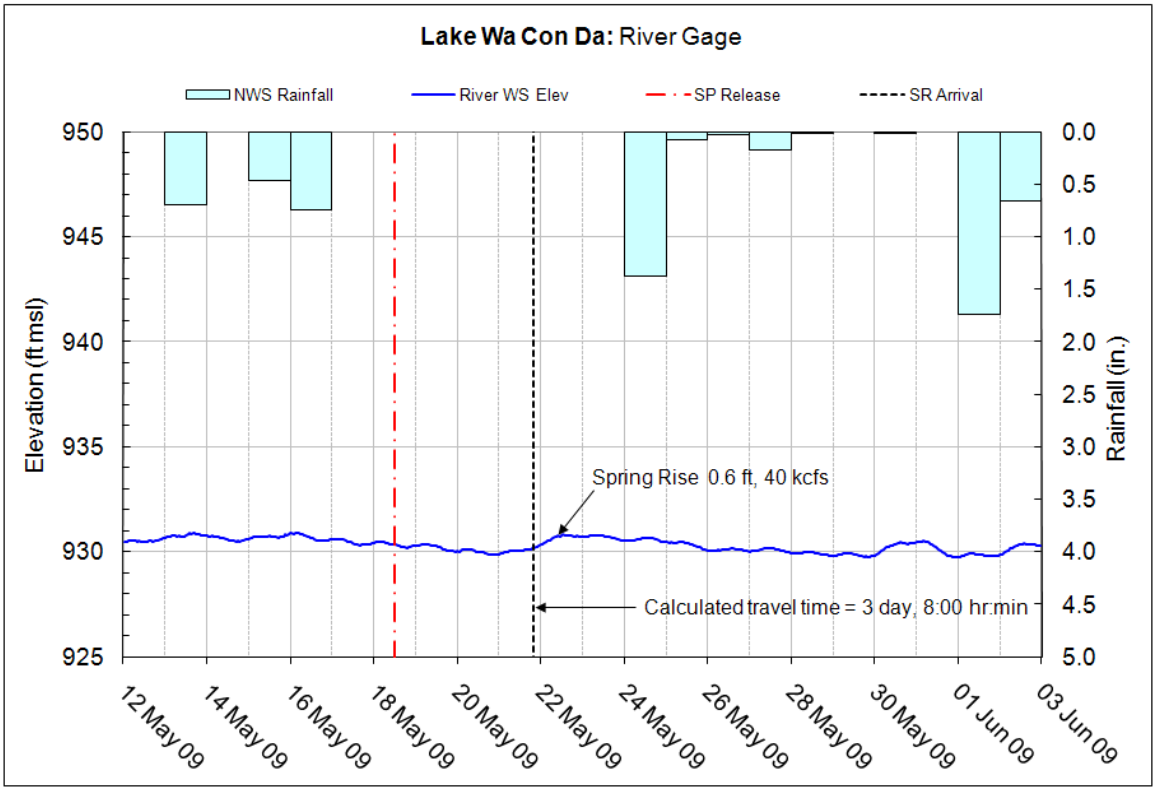

Figure 10.18.3 – Spring rise at Lake Wa Con Da

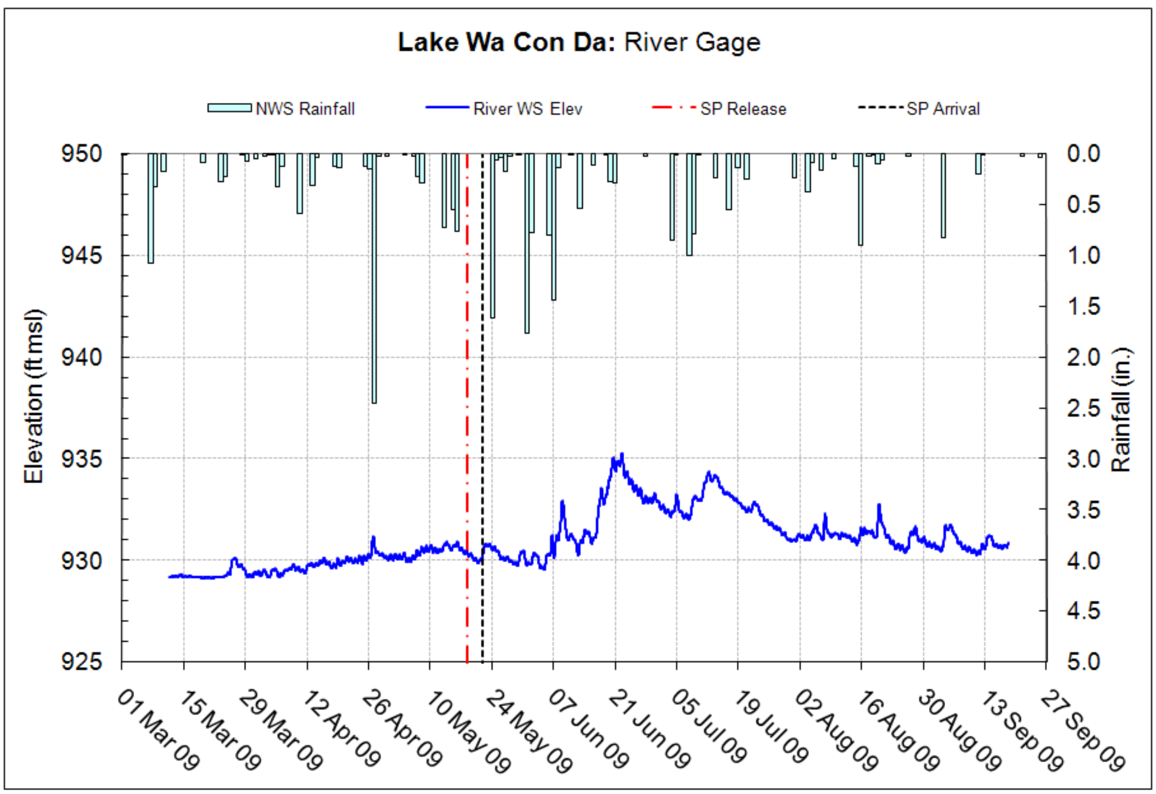

Figure 10.18.4 – Full monitoring record at Lake Wa Con Da

10.19 USGS Nebraska City

The USGS Missouri River Nebraska City gage is located on the right bank of the Missouri River at river mile 562.6 to the east of Nebraska City, NE and upstream of the Morton Beltway Bridge (Figure 10.19.1). Figure 10.19.2 shows the created spring rise produced by the spring pulse released from Gavins Point Dam. The created spring rise at this site was 0.9 ft. Figure 10.19.3 shows the full monitoring record with the travel time of the spring pulse noted.

Figure 10.19.1 – USGS Nebraska City location

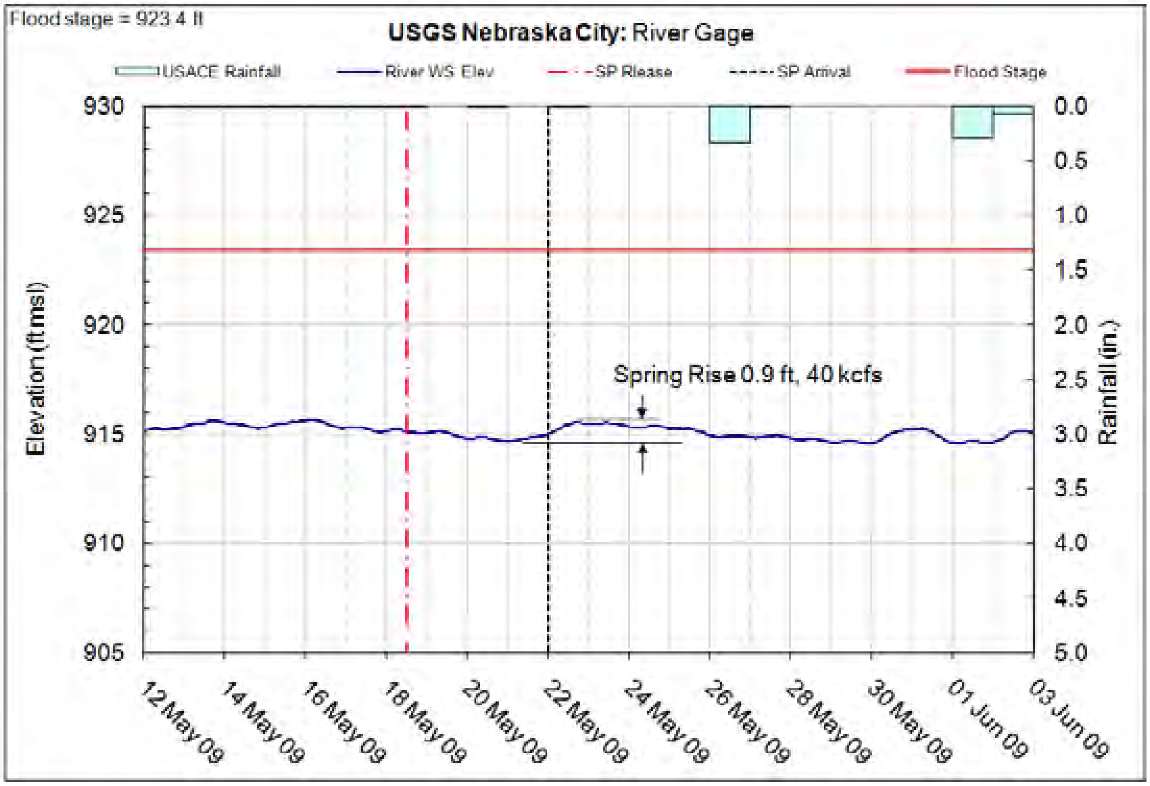

Figure 10.19.2 – Spring rise at USGS Nebraska City

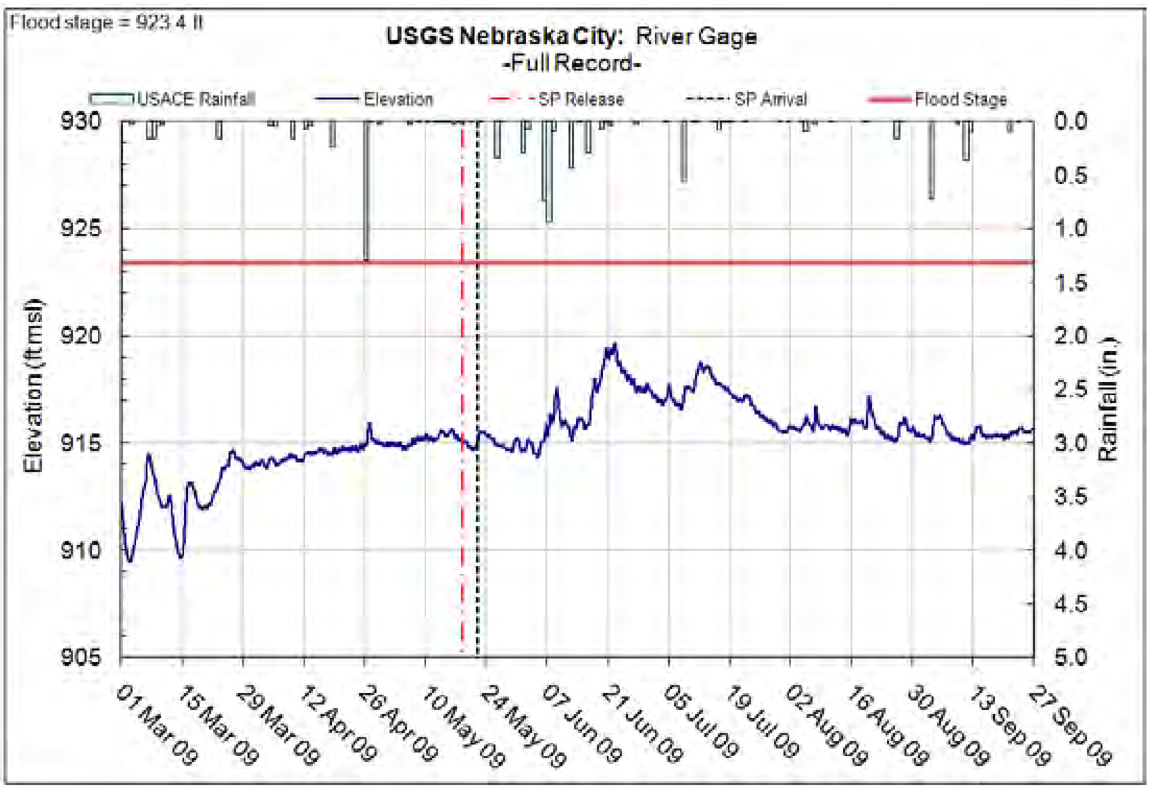

Figure 10.19.3 – Full monitoring record at Nebraska City

10.20 L-575 Structure No. 23

Levee Unit L-575 is a federal levee located near Nebraska City on the left bank of the Missouri River (Figure 10.20.1). This levee protects 73,320 acres of primarily agricultural land along the Missouri River from Plum Creek to the Nishnabotna River. Forty-five drainage structures convey water from the landward side of the 45-mile-long levee to the Missouri River. Drainage structure No. 23 is located about 6 miles southwest of Hamburg, IA at river mile 545.9 between the Upper and Lower Kansas Bends of the Missouri River. Drainage structure No. 23 has two 54-in. corrugated metal pipes (CMPs) with flap and slide gates and one pump (Figure 10.20.2, top left) rated at 22.5 cfs with a head of 25 ft. A data collection platform (DCP) was installed in November 2008.

Two staff gages and a DCP that records and transmits both the RS and LS water surface elevation were installed at this location. The riverside orifice line of the DCP is located near the outlet of the culverts and the landside orifice line is located in the ponding area upstream of the culverts. The culverts' inlet elevation is 895.96 ft (msl), their outlet elevation is 894.79 ft (msl), and the elevation of the top of the levee above the culverts is 915.6 ft (msl). A drainage ditch approximately 800 ft in length connects the culverts' outlet with the Missouri River. The old data-logger landside and riverside gage sites are shown in Figure 8.20.2; these are similar in location to the DCP orifice-line locations.

Field elevations were surveyed in 2009. The elevation of the LS left bank field is 901.6 ft (msl) and the LS right bank field is 901.9 ft (msl). The lower bank elevation is used in the analysis and the figures. The elevation of the RS bank and field is 900.9 ft (msl). Flows were estimated at the site by lagging the flow records of USGS Nebraska City and USGS Rulo to the site based on peaks and then interpolating flows based on river miles.

Results and Discussion

- Table 10.20.1 summarizes the results for the May 2009 and March 2008 created spring rises, and the Missouri River flows estimated to reach the outlet and inlet of the site's drainage structure.
- Table 10.20.2 summarizes the socioeconomic impacts produced by the natural spring rises at the site in May 2009 and March 2008. Durations of impacts were shorter in 2009 than they were in 2008. Gate closures in 2008, for example, varied from 10.5 to 12.3 days in 2008 while they were closed for a continuous 39 days in 2008.
- Figure 10.20.3 shows the spring pulse release on May 18 and its arrival time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise created by the spring pulse was approximately 0.6 ft. Based on the attenuation analysis, the spring pulse accounts for 3.9 kcfs of the total 40-kcfs Missouri-River flow at this river mile, or 9.8% of the total flow.
- Figure 10.20.4 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site shown.
- Figure 10.20.5 shows the full period of the monitoring record with the inlet- and the outlet-invert elevations of the drainage structure.
- Figure 10.20.6 shows the lowest 2009 surveyed field elevations on the LS and RS of the levee.
- Figure 10.20.7 combines the information gained from the inlet and outlet inverts and the field elevation to separate out possible socioeconomic impacts produced by natural

spring rises during the monitoring period. Pumping, gate closures, and a short period of possible overland flooding occurred.

- Figure 10.20.8 shows the estimation of the impact threshold for gate closure and pumping at the L-575 Structure No. 23 site. The flows were 51 kcfs in the Missouri River when gate closures and pumping occurred in 2009.
- Figure 10.20.9 shows the estimation of the RS flooding threshold. Missouri River flows at the river mile of the site must be 57 kcfs or higher to produce RS flooding.
- Figure 10.20.10 shows the estimation of the Missouri River flows required to reach the outlet of the site. The estimated flow in the Missouri River at the site required to reach the outlet invert of the site was 32 kcfs based on the 2009 record. An outlet-flow threshold could not be estimated using the 2008 data because the water elevation is over the outlet invert for the full 2008 record (Figure 10.18.15).
- Figure 10.20.11 shows an estimate of the inlet-invert flow threshold. Because the LS water elevation does not drop below the invert elevation, the threshold was estimated based on the RS elevation dropping below the inlet-invert elevation. The Missouri River has to be over 36 kcfs to reach the inlet invert elevation. A flow threshold was estimated using the 2008 data using the same technique (Figure 10.18.14), and the inlet-invert flow threshold for 2008 was 37 kcfs.
- Figure 10.20.12 shows the LS flooding-flow threshold estimation using the 2008 monitoring record and the field elevation surveyed in 2009. Flows in the Missouri River were around 82 kcfs when flooding occurred.
- Figure 10.20.13 shows the estimation of the Missouri River flow at which RS flooding occurs using the 2008 monitoring record and the field elevation surveyed in 2008. Flows in the Missouri River were around 57 kcfs when flooding occurred.
- Figures 10.20.14 and 10.20.15 show the estimation of inlet- and outlet-flow thresholds using the 2008 record. The inlet-flow threshold is 37 kcfs. The outlet-flow threshold could not be estimated because the outlet invert of the drainage structure was under water for the full monitoring period.

Conclusions

No socioeconomic impacts were created by the May 2009 spring pulse released from Gavins Point Dam. Natural rises in the river did appear to produce a short period of overbank flooding (0.5 days) and period of 0.2 to 7.4 days of pumping behind closed gates. The rise produced by the May created spring pulse could not be separated from background effects on the river. Based on the attenuation analysis, the May spring pulse accounted for 3.9 kcfs of the total 40-kcfs Missouri-River flow at this river mile, or 9.8% of the total flow. Although the outlet-invert threshold for the 2008 record could not be determined due to the water elevation being over the outlet invert for the full period of record, the inlet-flow threshold could be estimated. The 2009 inlet-flow threshold was 36 kcfs and the 2008 inlet threshold flow was 37 kcfs.

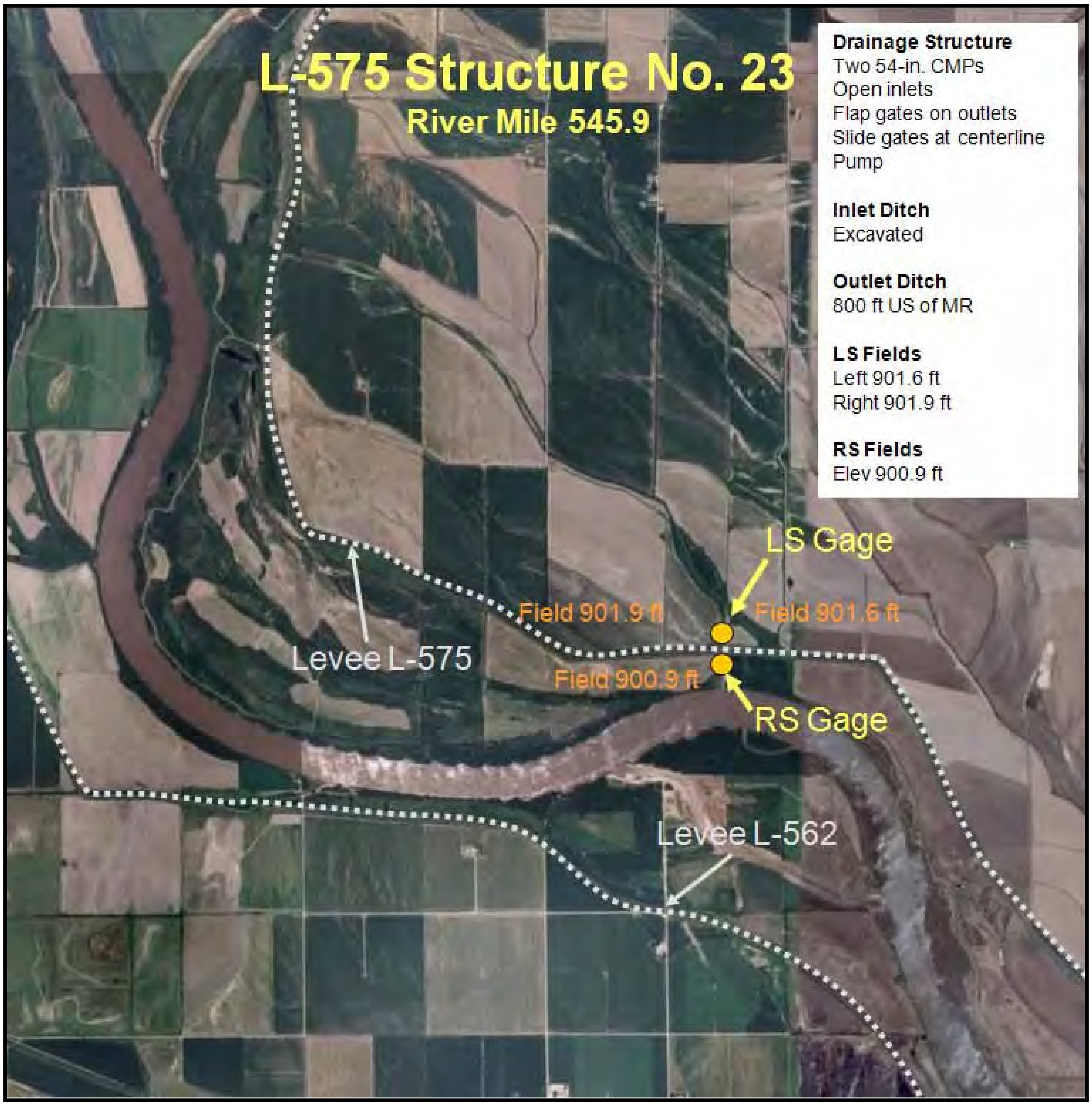

Figure 10.20.1 – L-575 Structure No. 23 location

Figure 10.20.2 – L-575 Structure No. 23 site. LS data logger installed on pump station (top left). RS data logger installed between 54-in. CMPs (top right). Top of levee looking landward (center left). Top of levee looking riverward (center right). Top of levee looking at RS structure and fields (bottom left). Top of levee looking at riverside fields (bottom right).

Table 10.20.1 – L-575 Structure No. 23 results

Spring Pulse from Gavins Point Dam

	May-09	***Mar-08***
Created spring rise, ft	0.6	0
Estimated created spring rise flow, kcfs	3.9	1.6
Estimated MR flow at site, kcfs	40	31
% of MR flow	9.8	5.2

Outlet-flow Threshold

	May-09	***Mar-08***
Elev, ft	894.79	894.79
Estimated MR flow at site, kcfs	32	too low

Inlet-flow Threshold

	May-09	***Mar-08***
Elev, ft	895.96	895.96
Estimated MR flow at site, kcfs	36	37

Table 10.20.2 – L-575 Structure No. 23 NSR socioeconomic impacts

2009 Natural Spring Rise Impacts

	LS Flooding	***RS Flooding***	***Pumping***	***Gate Closure***
Elev, ft	901.6	900.9	899.4	899.4
Impact duration, dy	no flooding	0.5	0.2 - 7.4	10.5 - 12.3
Estimated MR flow at site, kcfs	n.a.	57	51	51

2008 Natural Spring Rise Impacts

	LS Flooding	***RS Flooding***	***Pumping***	***Gate Closure***
Elev, ft	901.6	900.9	899.0	899.0
Impact duration, dy	11	24	39	39
Estimated MR flow at site, kcfs	82	57	49	49

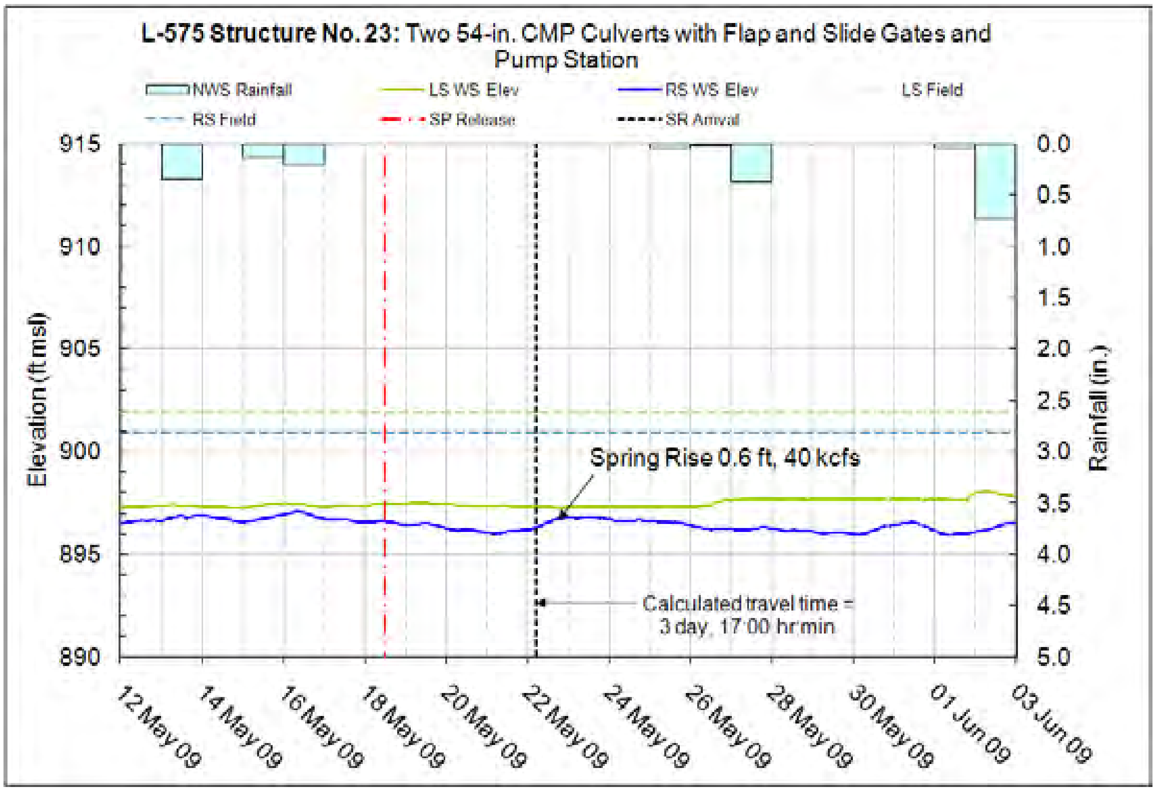

Figure 10.20.3 – Spring rise at L-575 Structure No. 23

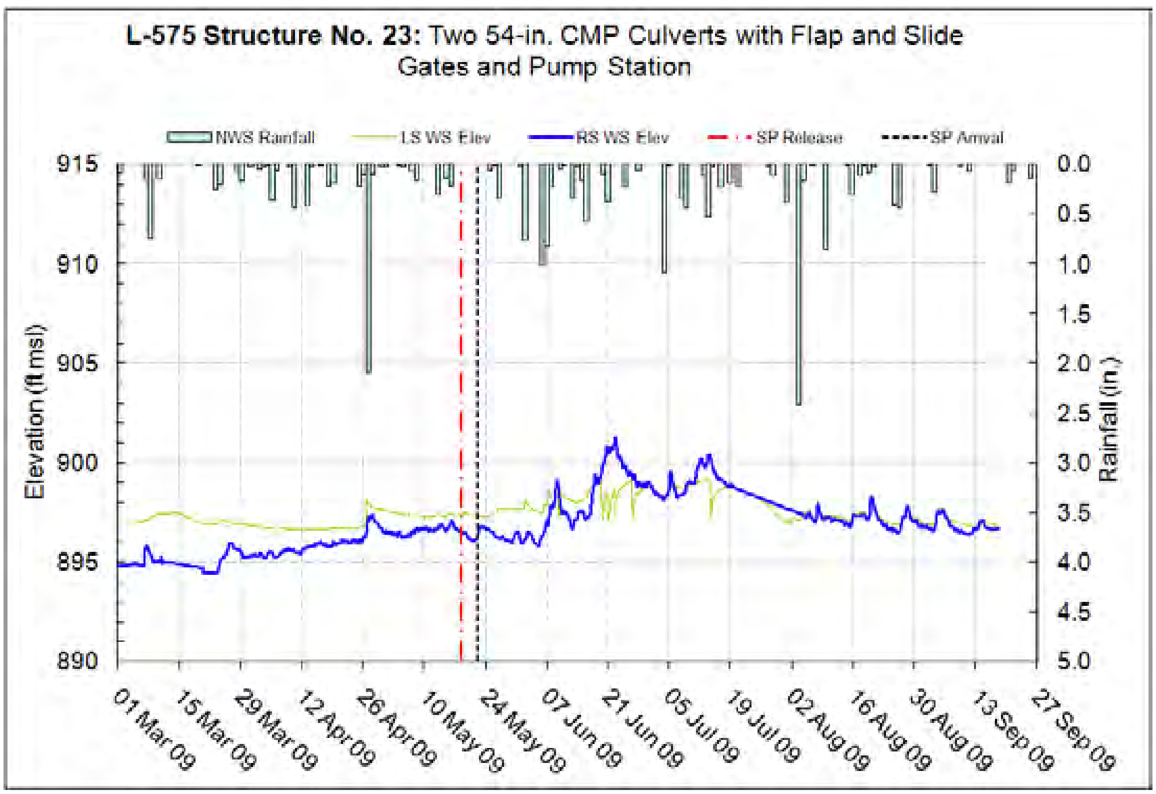

Figure 10.20.4 – Full monitoring record at L-575 Structure No. 23

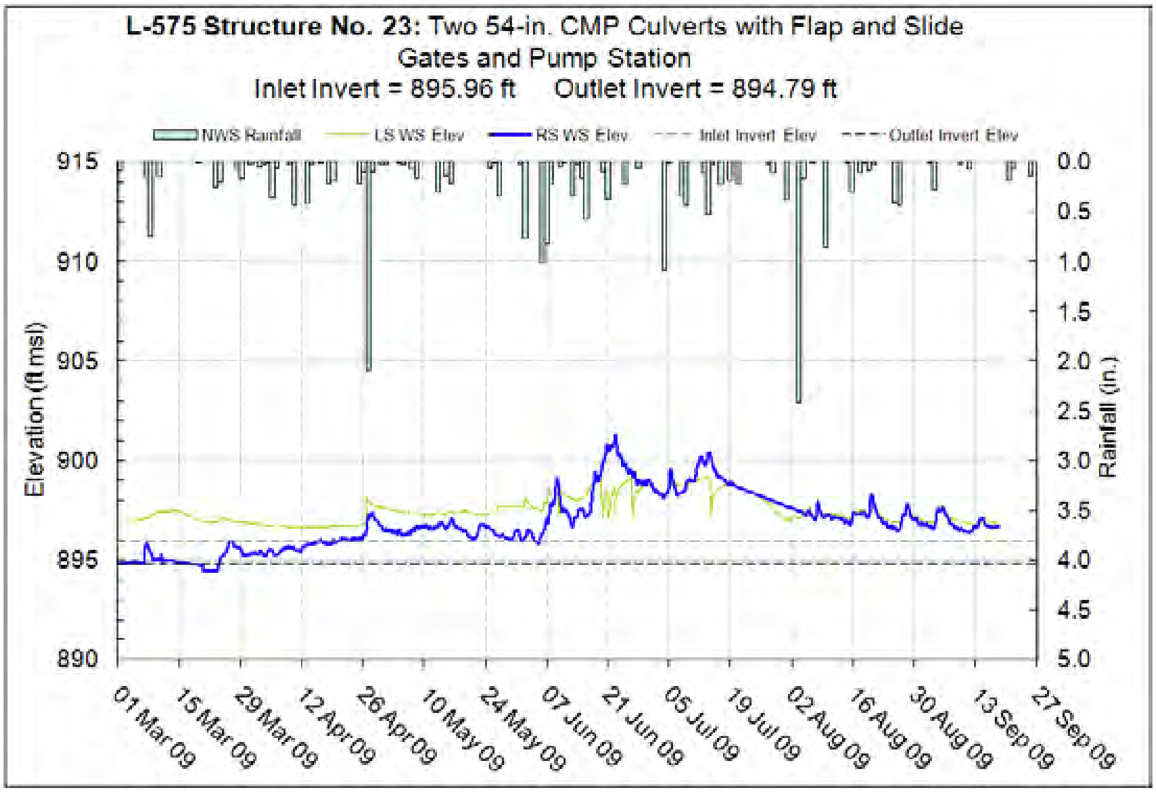

Figure 10.20.5 – Invert elevations, L-575 Structure No. 23

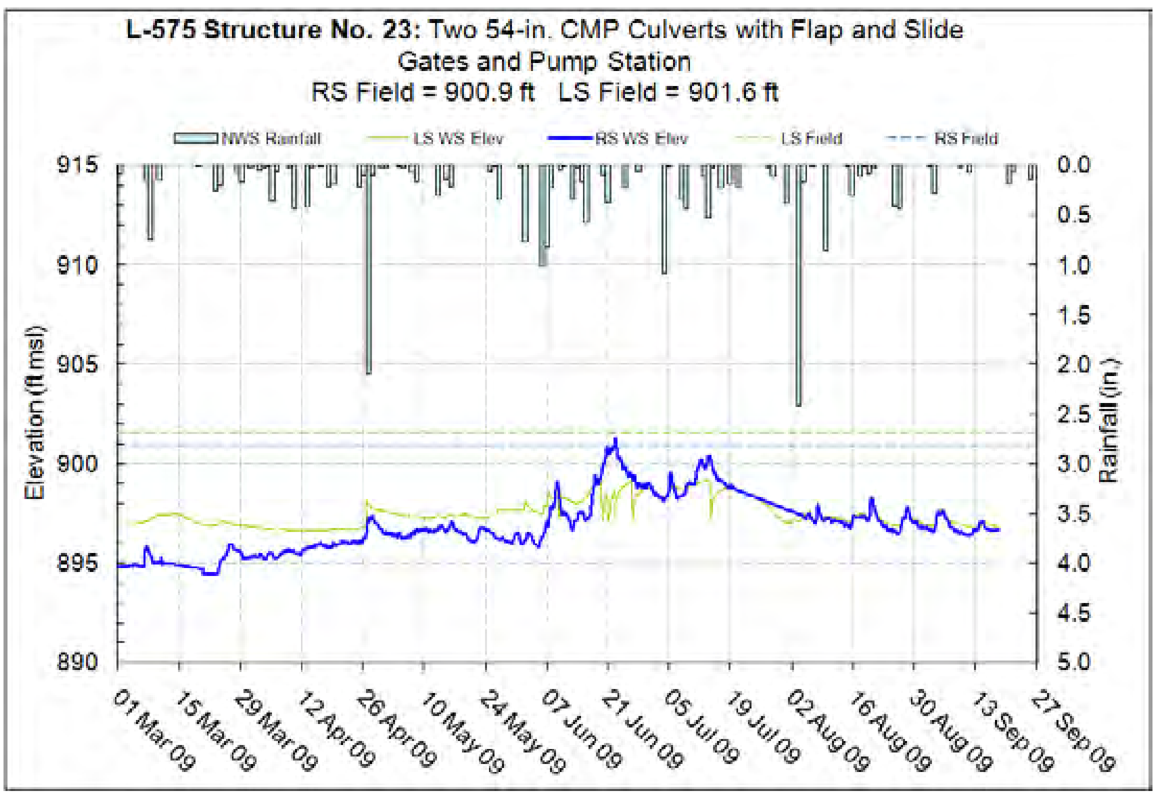

Figure 10.20.6 – Surveyed field elevations, L-575 Structure No. 23

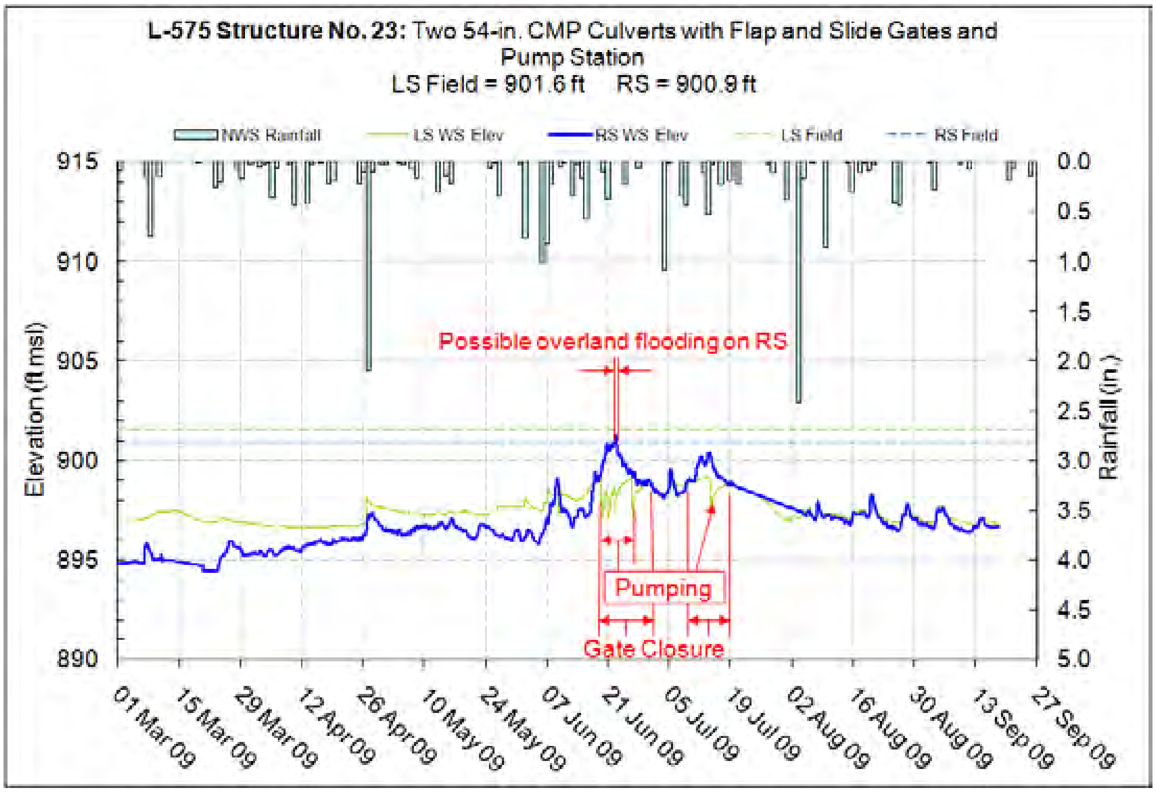

Figure 10.20.7 – NSR socioeconomic impacts, L-575 Structure No. 23

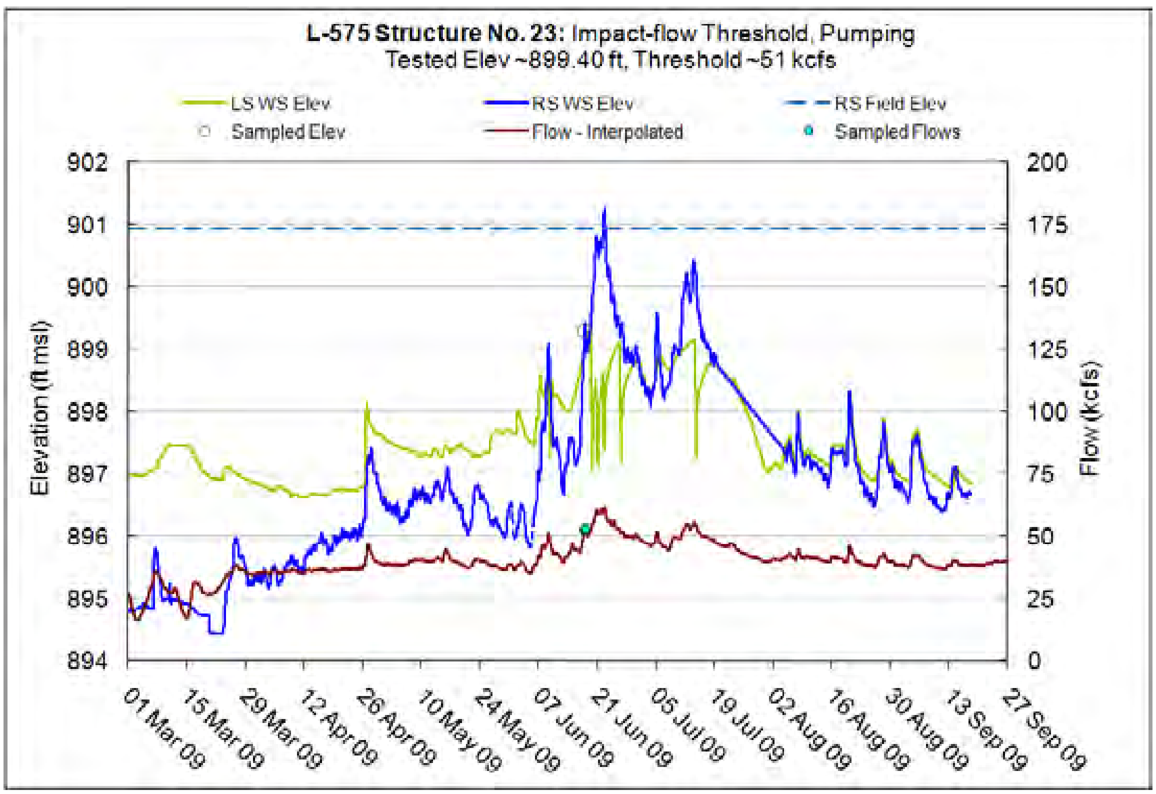

Figure 10.20.8 – Impact-flow threshold, L-575 Structure No. 23 (gate closure and pumping)

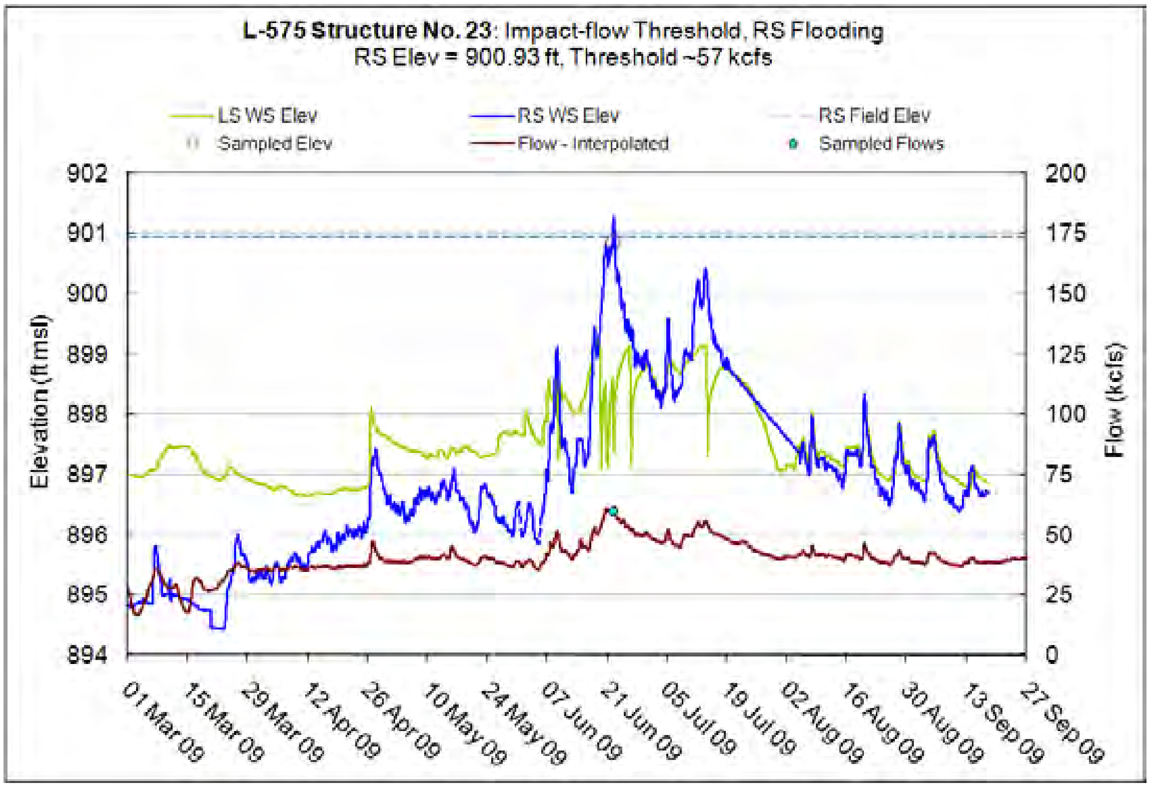

Figure 10.20.9 – Impact-flow threshold, L-575 Structure No. 23 (overbank flooding)

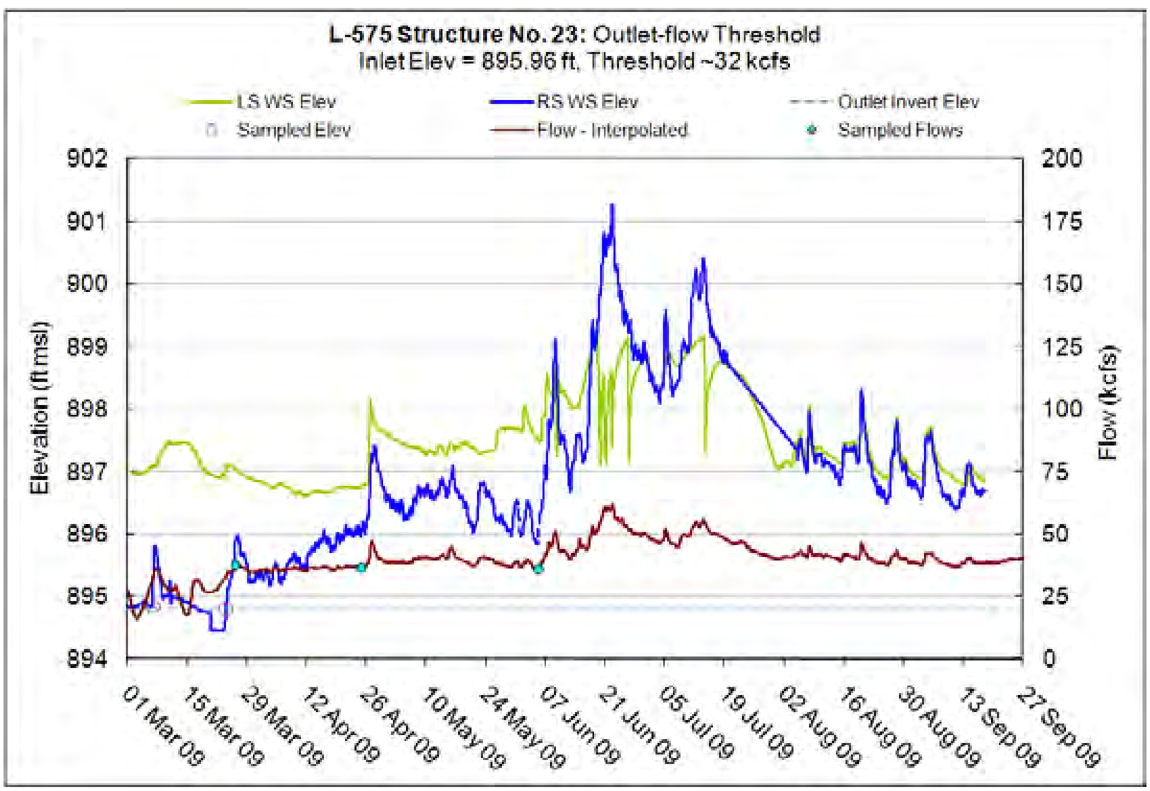

Figure 10.20.10 – Outlet-flow threshold, L-575 Structure No. 23

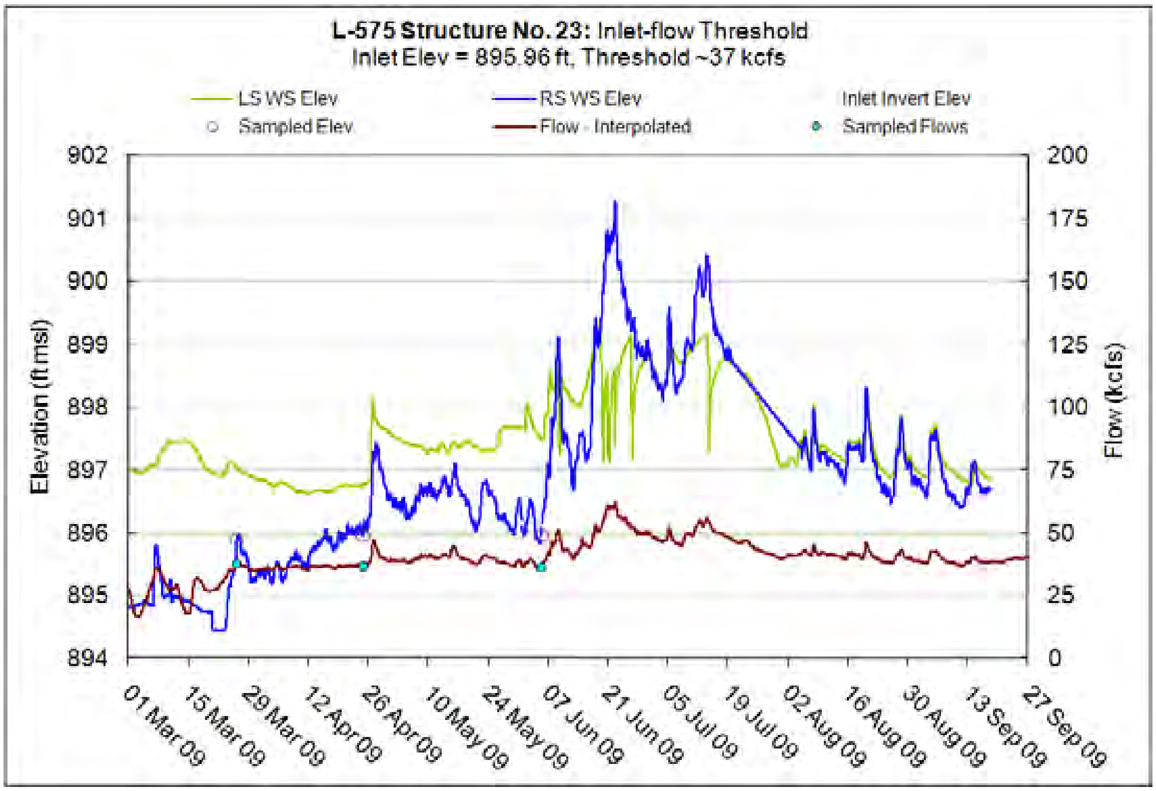

Figure 10.20.11 – Inlet-flow threshold, L-575 Structure No. 23

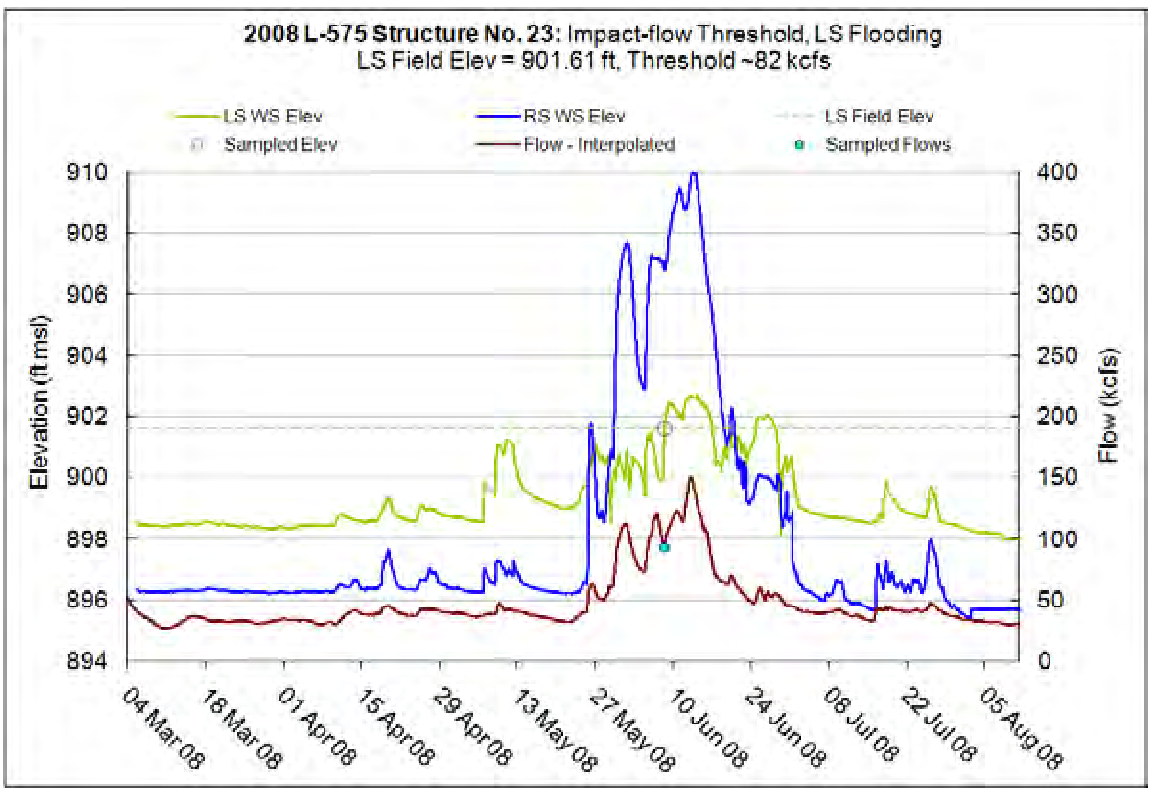

Figure 10.20.12 – Impact-flow threshold (LS flooding), L-575 Structure No. 23 (2008 record)

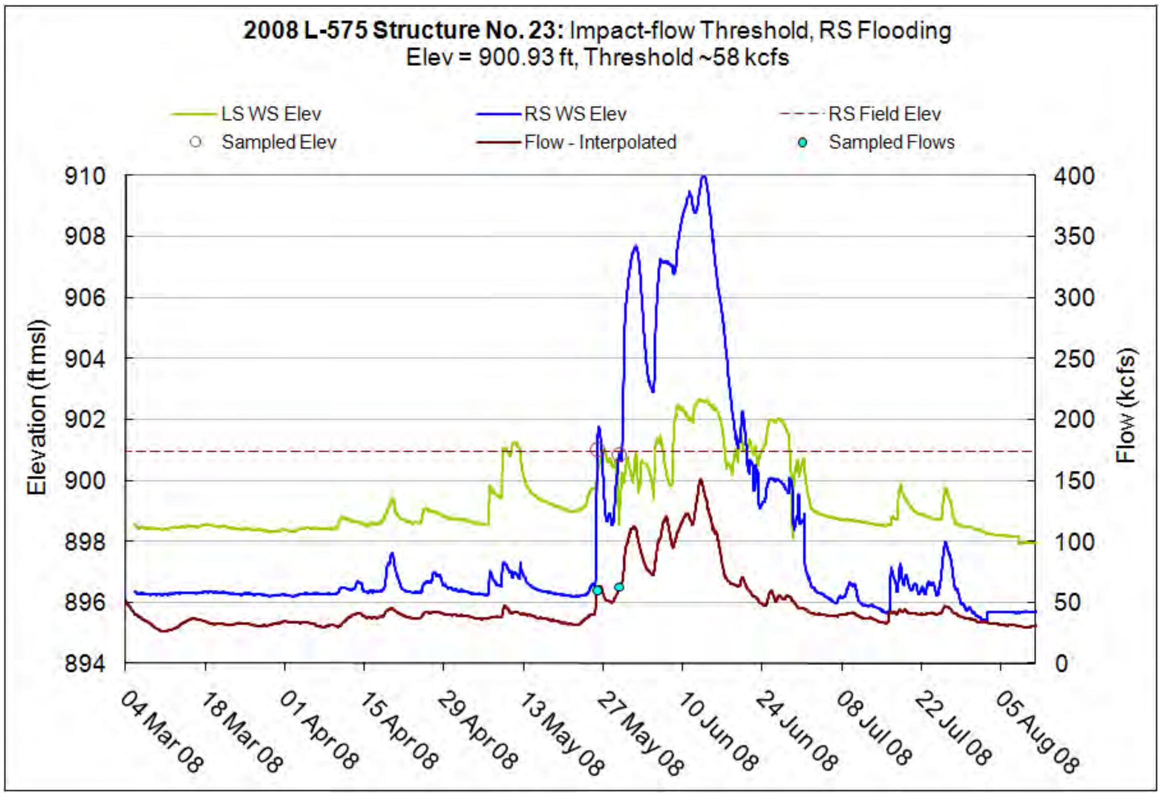

Figure 10.20.13 – Impact-flow threshold (RS flooding), L-575 Structure No. 23 (2008 record)

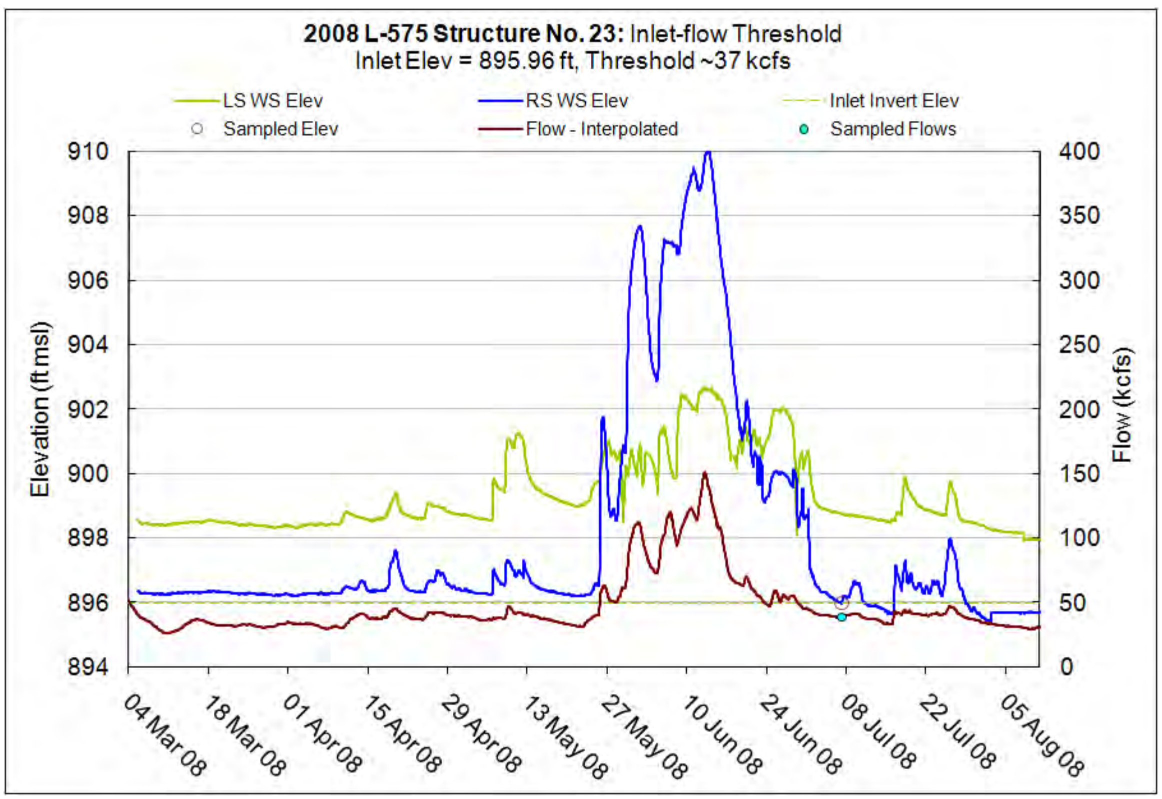

Figure 10.20.14 – Inlet-flow threshold, L-575 Structure No. 23 (2008 record)

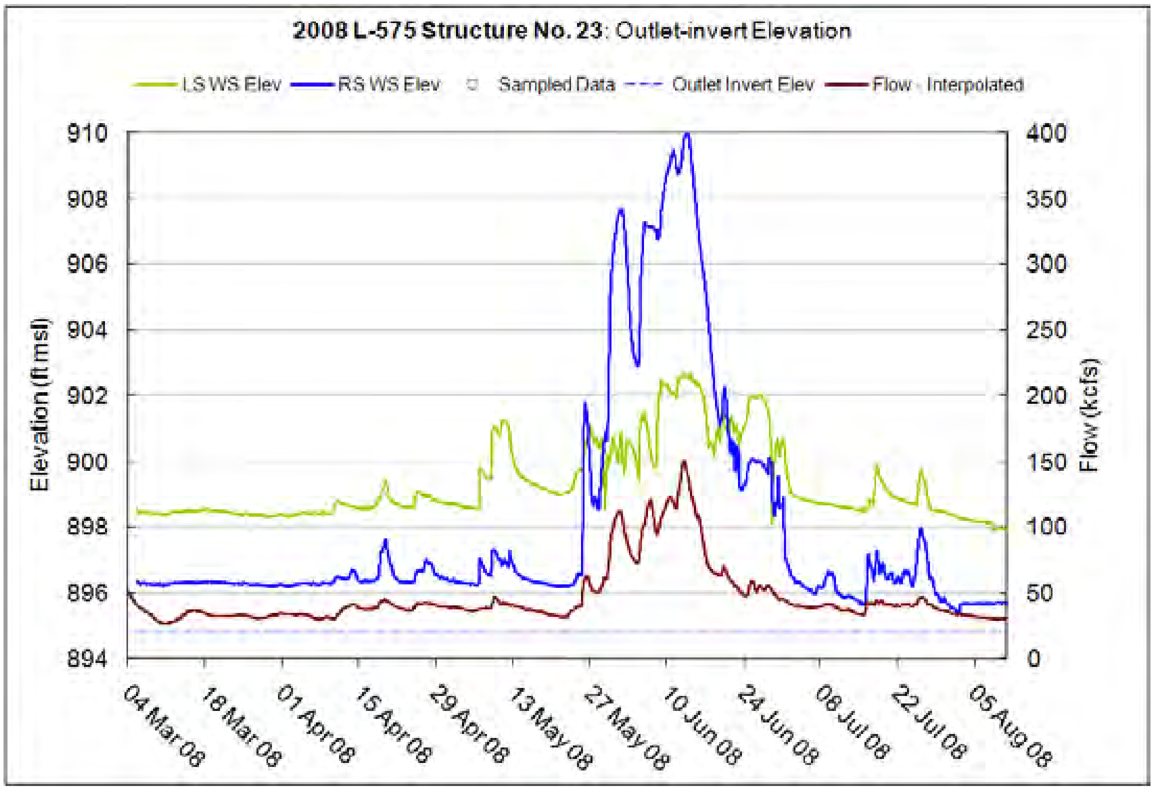

Figure 10.20.15 – Outlet-invert elevation, L-575 Structure No. 23 (2008 record)

10.21 USACE Brownville

The USACE Missouri River Brownville gage is located at river mile 535.3 on the right bank of Missouri River east of Brownville, NE (Figure 10.21.1). Figure 10.21.2 shows the created spring rise produced by the spring pulse released from Gavins Point Dam. The created spring rise at this site was approximately 0.6 ft. Figure 10.21.3 shows the full monitoring record with the travel time of the spring pulse noted.

Figure 10.21.1 – USGS Brownville location

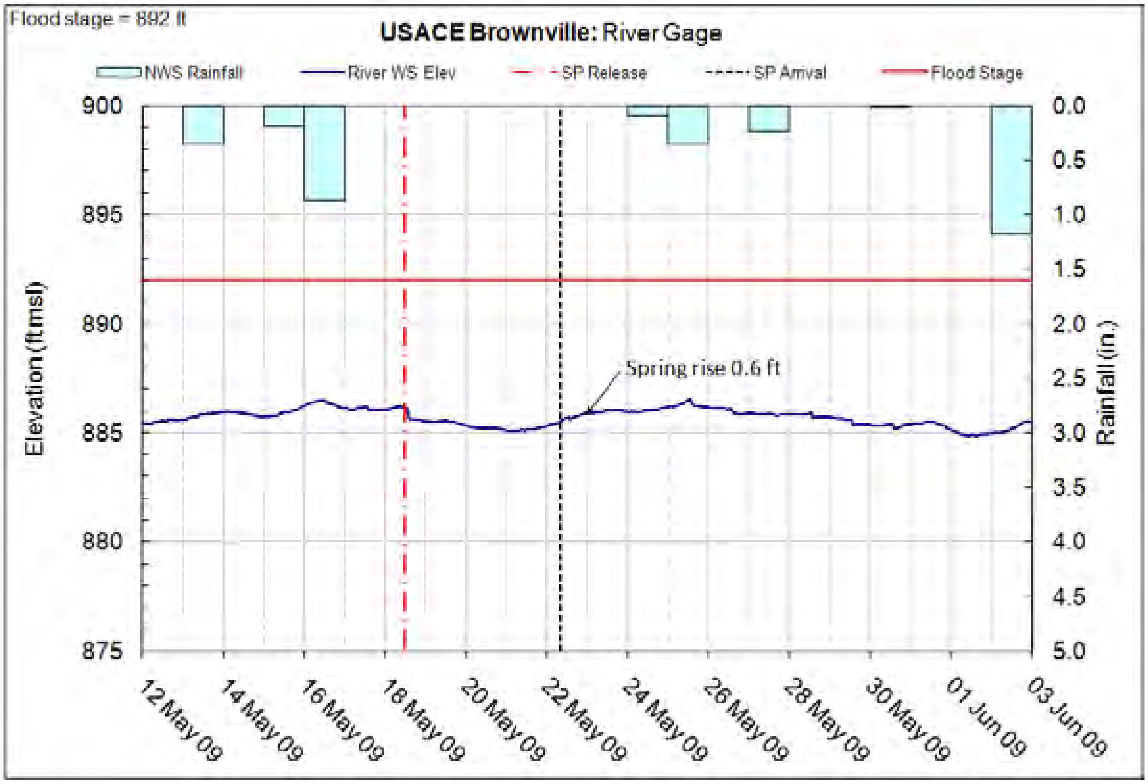

Figure 10.21.2 – Spring rise, USACE Brownville

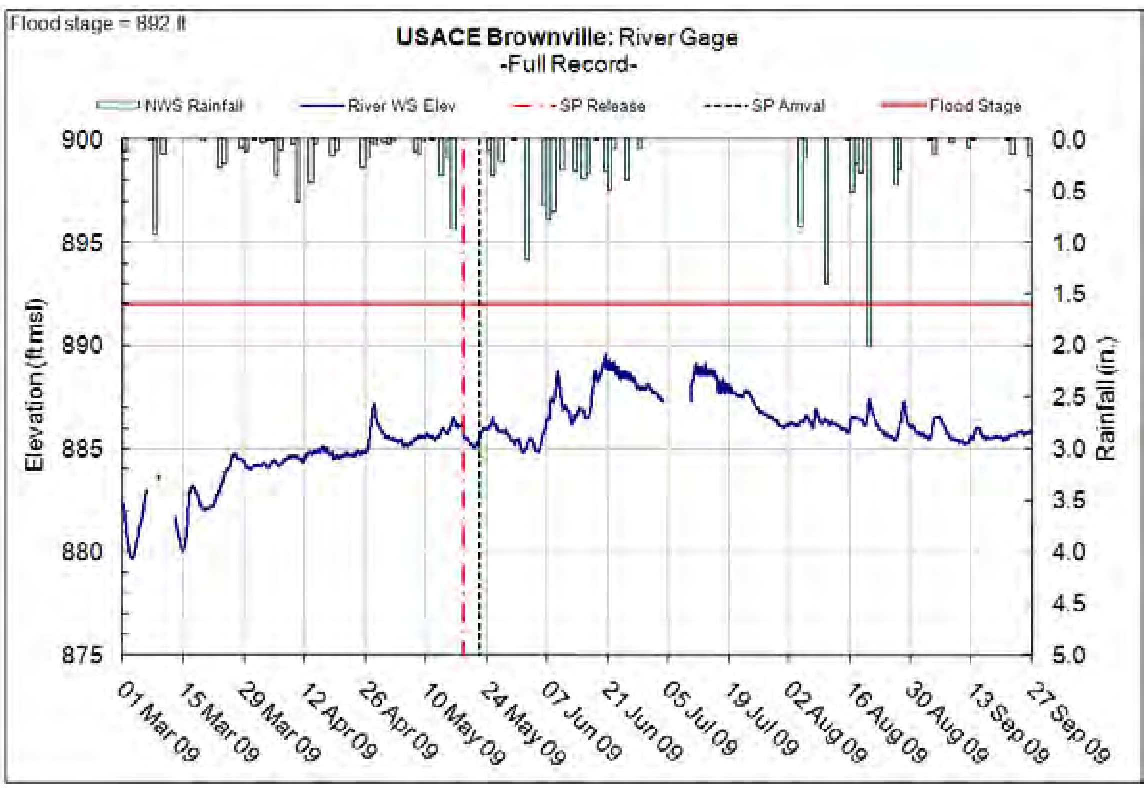

Figure 10.21.3 – Full monitoring record, USACE Brownville

10.22 L-536 Structure No. 8

Levee Unit L-536 is a federal levee located near Rock Port, MO on the left bank of the Missouri River (Figure 10.22.1). It protects 13,030 acres of primarily agricultural land along the Missouri River from Rock Creek to Mill Creek. Drainage Structure No. 8 along this levee is located approximately 9 miles southwest of Rock Port at river mile 521.5. The drainage structure has two 72-in. CMPs with open inlets (Figure 10.22.2, top right), and slide gates (Figure 10.22.2, bottom left), and one pump rated at 22.5 cfs with a 25-ft head (Figure 10.22.2, top left). The flap gates were found lying on the levee at this site in early 2009 (Figure 10.22.2, bottom left).

Two gages were installed in the same locations as last year at this location. The RS gage is located near the outlet of the two culverts, and the landside gage is located in the ponding area upstream of the culverts. The culverts' inlet elevation is 871.2 ft (msl), their outlet elevation is 869.14 ft (msl), and the elevation of the top of the levee above the culverts' inlets is 889.7 ft (msl). A drainage ditch approximately 800 ft in length connects the culverts' outlets with the Missouri River. The landside and riverside gage sites are shown in Figure 10.20.2.

Field elevations were surveyed in 2009. The elevation of the field on the LS right bank is 879.9 ft (msl). Two survey points were taken on the left bank and were 880.6 ft (msl) and 879.9 ft (msl). The lowest field elevation is used in the analysis. The elevation of a cut in the field on the RS of the levee about 100 ft from the drainage structure is 879.4 ft (msl). The elevation of the road on the RS of the levee is 880.0 ft (msl). Flows were estimated at the site by lagging the flow records of USGS Nebraska City and USGS Rulo to the site based on peaks and then interpolating flows based on river miles.

Results and Discussion

- Table 10.22.1 summarizes the results for the May 2009 and March 2008 created spring rises, and the Missouri River flows estimated to reach the outlet and inlet of the site's drainage structure.
- Table 10.22.2 summarizes the socioeconomic impacts produced by the natural spring rises at the site in May 2009 and March 2008.
- Figure 10.22.3 shows the spring pulse release on May 18 and its arrival time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise created by the spring pulse was as estimated 0.2 ft at this site. Based on the attenuation analysis, the spring pulse accounts for 3.6 kcfs of the total 41-kcfs Missouri-River flow at this river mile, or 8.8% of the total flow.
- Figure 10.22.4 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site shown.
- Figure 10.22.5 shows the full period of the monitoring record with the inlet- and the outlet-invert elevations of the drainage structure.
- Figure 10.22.6 shows the lowest 2009 surveyed LS field elevation.
- Figure 10.22.7 combines the information gained from the inlet and outlet inverts and the field elevation to separate out possible socioeconomic impacts produced by natural spring rises during the monitoring period. It appears the slide gates were closed around July 27 but this closure does not appear to be in response to high river flows. There were no identified socioeconomic impacts at this site during the 2009 monitoring period.

- § Figure 10.22.8 shows the estimation of the inlet-invert flow threshold from the 2008 record. Based on the 2008 estimate, the Missouri River needs to be over 37 kcfs to reach the inlet invert of the drainage structure. An outlet-invert threshold flow could not be estimated from either the 2009 or 2008 data because the water elevation is over the outlet invert for the entire record.
- § Figure 10.22.9 shows the estimation of the 2008 inlet-flow threshold.
- § Figure 10.22.10 shows the estimation of the 2008 flooding flow threshold for the RS of the site based on surveyed field elevations. It was originally concluded in the 2008 monitoring report that no flooding occurred at this site and that the pump was run. The addition of the field elevations surveyed in 2009, however, show that overbank flooding occurred at this site. The estimated flow that caused the LS flooding in 2008 was 120 kcfs in the Missouri River at the site or 104 kcfs at the Nebraska City gage.
- § Figure 10.22.11 shows the estimation of the 2008 flooding flow threshold for the LS of the site based on surveyed field elevations. The estimated flow that caused the RS flooding in 2008 was 85 kcfs in the Missouri River at the site or 66 kcfs at the Nebraska City gage.
- § Figure 10.22.12 shows the estimation of the 2008 flow that resulted in gate closure. The estimated flow that caused the gate to close in 2008 was 76 kcfs in the Missouri River at the site or 57 kcfs at the Nebraska City gage.

Conclusions

No socioeconomic impacts were created at this site by either the created spring rise or natural spring rises in May 2009. The rise created by the created spring pulse could not be separated from background effects on the river. Based on the attenuation analysis, the spring pulse accounts for 3.6 kcfs of the total 41-kcfs Missouri-River flow at this river mile, or 8.8% of the total flow. Field elevations surveyed in 2009 were added to the 2008 monitoring records. Overbank flooding did occur at this site in 2008 due to high natural spring rises. Landside flooding occurred when the Missouri River reached an estimated 120 kcfs at the site and 104 kcfs at the Nebraska City gage. Riverside flooding occurred when the Missouri River reached an estimated 85 kcfs at the site and 66 kcfs at the Nebraska City gage.

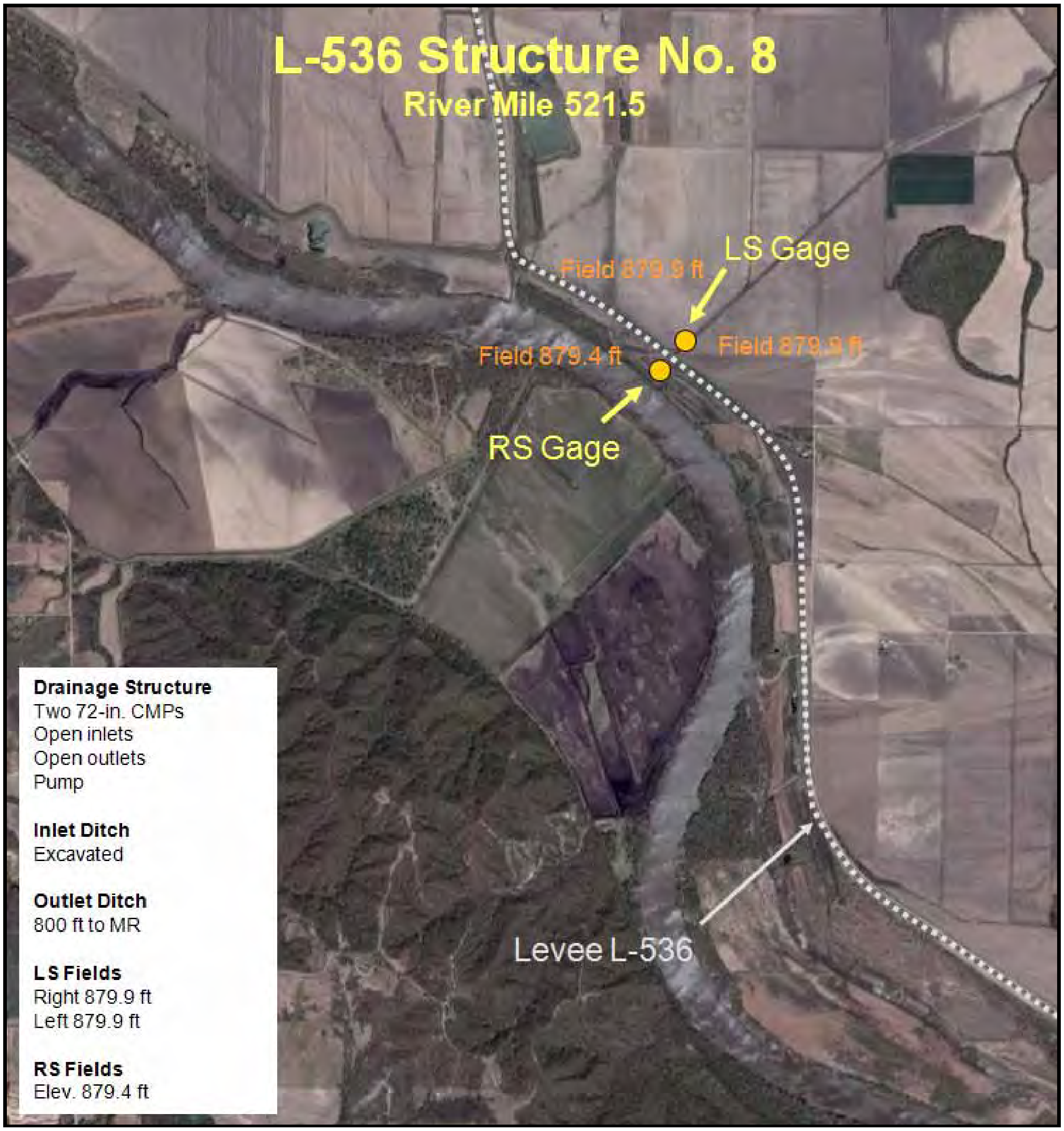

Figure 10.22.1 – L-536 Structure No. 8 location

Figure 10.22.2 – L-536 Structure No. 8 site and gages. LS gage (top left) and RS (top right) gage. Slide gates near centerline of levee and removed flap gate on levee bank (bottom left).

Table 10.22.1 – L-536 Structure No. 8 results

Spring Pulse from Gavins Point Dam	*May-09*	*Mar-08*
Created spring rise, ft	0.2*	n.a.
Estimated created spring rise flow, kcfs	3.6	1.3
Estimated MR flow at site, kcfs	41	33
% of MR flow	8.8	4.1

Outlet-flow Threshold	*May-09*	*Mar-08*
Elev, ft	869.14	869.14
Estimated MR flow at site, kcfs	n.a.	n.a.
Flow at nearest US gage, kcfs	n.a.	n.a.
Nearest US gage	NE City	NE City

Inlet-flow threshold	*May-09*	*Mar-08*
Elev, ft	871.20	871.20
Estimated MR flow at site, kcfs	37	37
Flow at nearest US gage, kcfs	36	33
Nearest US gage	NE City	NE City

*Partial spring rise

Table 10.22.2 – L-536 Structure No. 8 NSR socioeconomic impacts

2009 Natural Spring Rise Impacts	*LS Flooding*	*RS Flooding*	*Gate Closure*
Elev, ft	879.9	879.4	n.a.
Impact duration, dy	No Flooding	No Flooding	n.a.
Estimated MR flow at site, kcfs	No Flooding	No Flooding	n.a.
Flow at nearest US gage, kcfs	No Flooding	No Flooding	n.a.
Nearest US gage	NE City	NE City	NE City

2008 Natural Spring Rise Impacts	*LS Flooding*	*RS Flooding*	*Gate Closure*
Elev, ft	879.9	879.4	877.9
Impact duration, dy	10	20	20
Estimated MR flow at site, kcfs	120	85	76
Flow at nearest US gage, kcfs	104	66	57
Nearest US gage	NE City	NE City	NE City

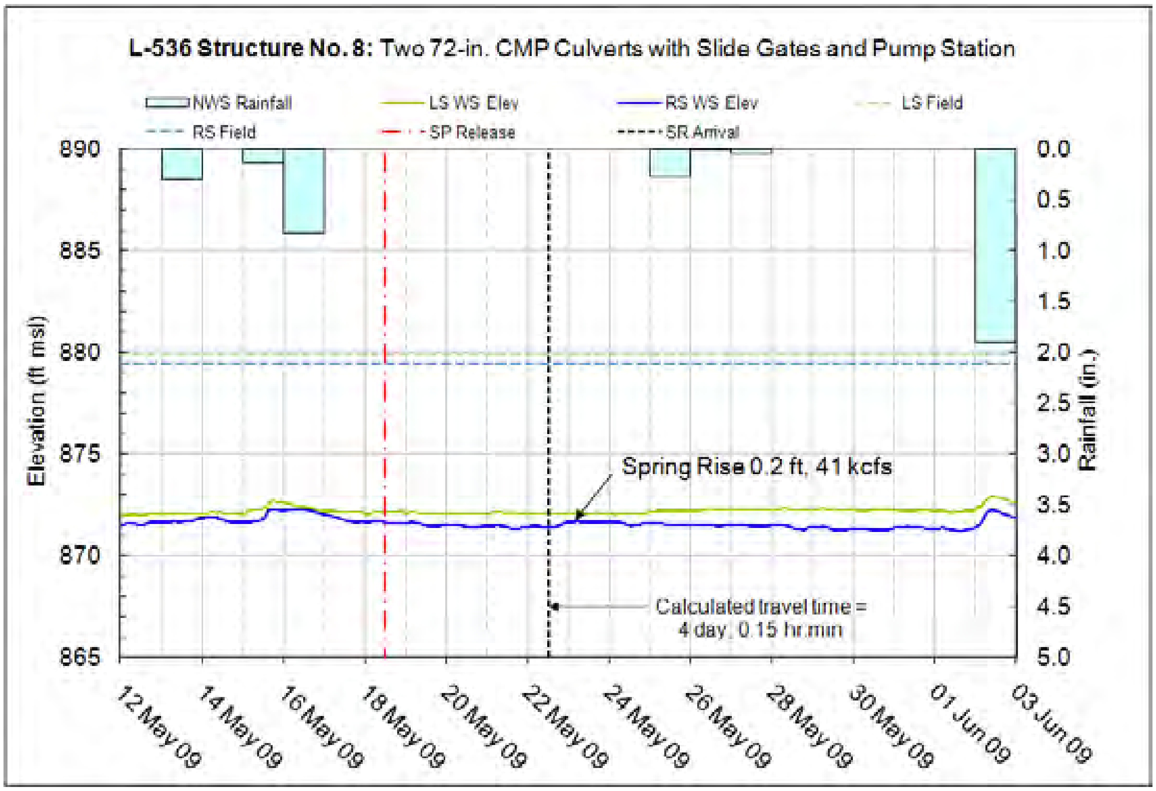

Figure 10.22.3 – Spring rise, L-536 Structure No. 8

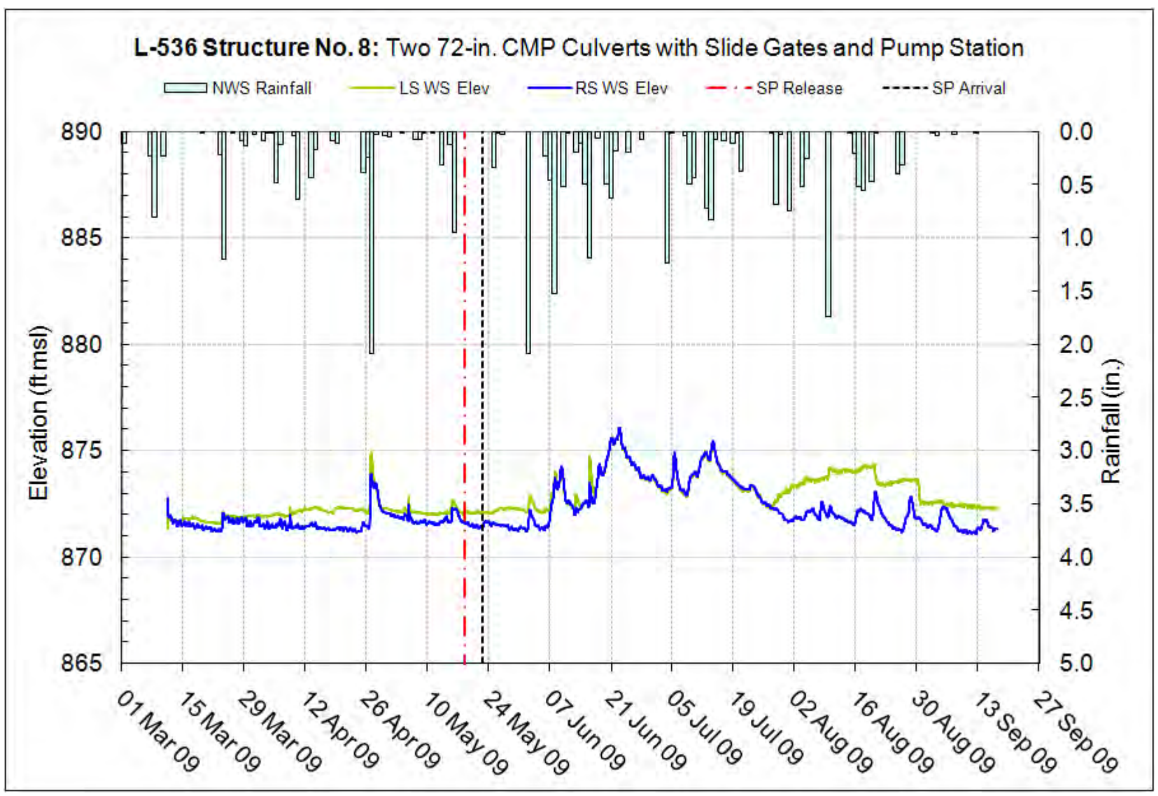

Figure 10.22.4 – Full monitoring record, L-536 Structure No. 8

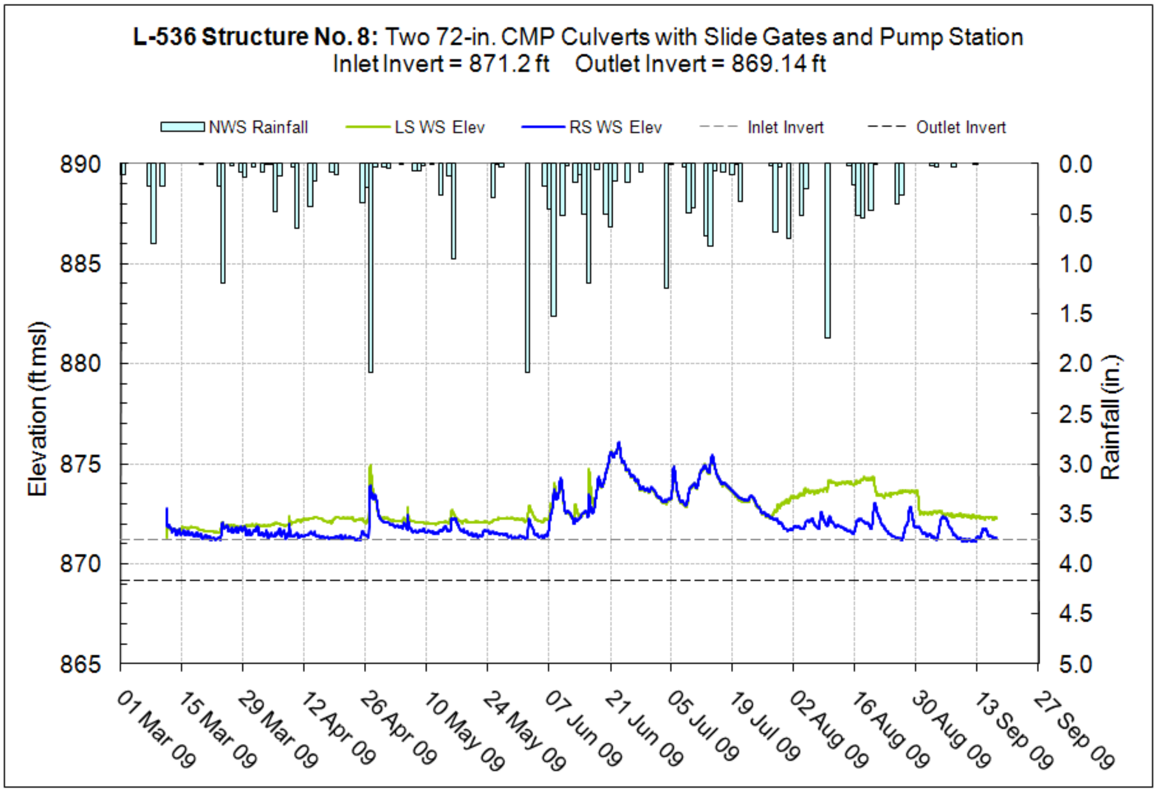

Figure 10.22.5 – Invert elevations, L-536 Structure No. 8

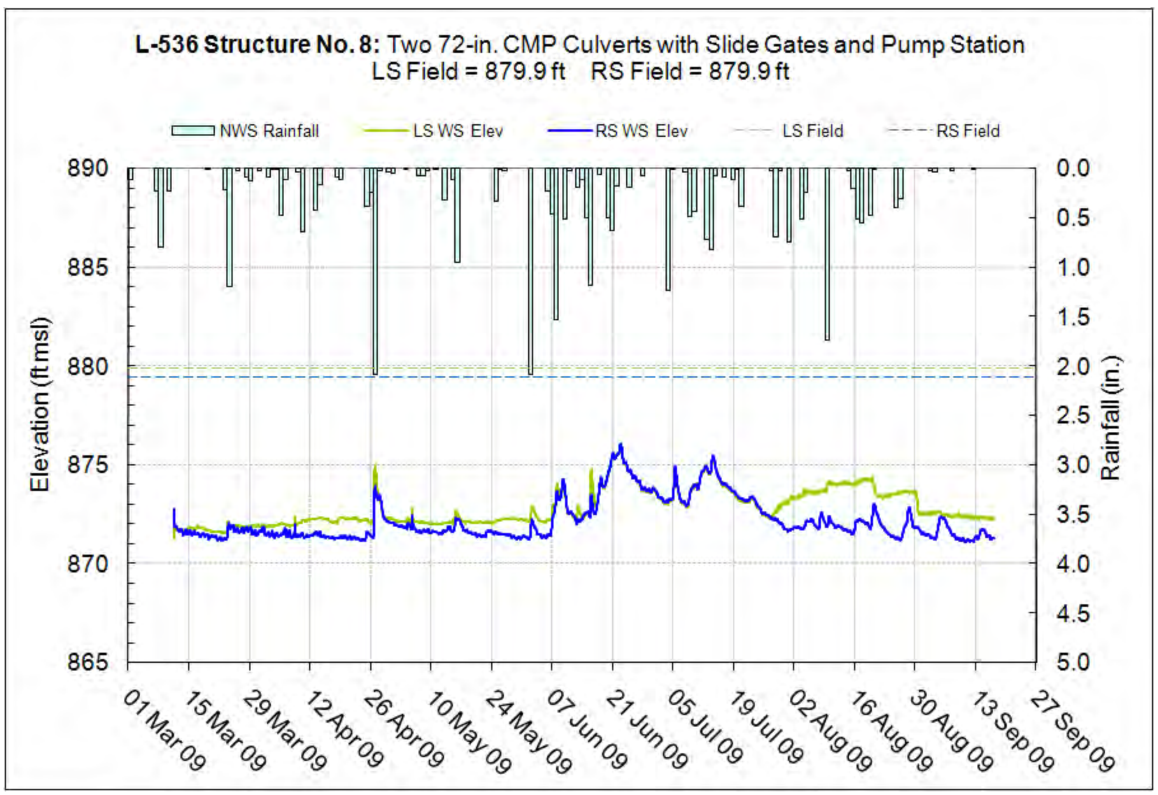

Figure 10.22.6 – Surveyed field elevations, L-536 Structure No. 8

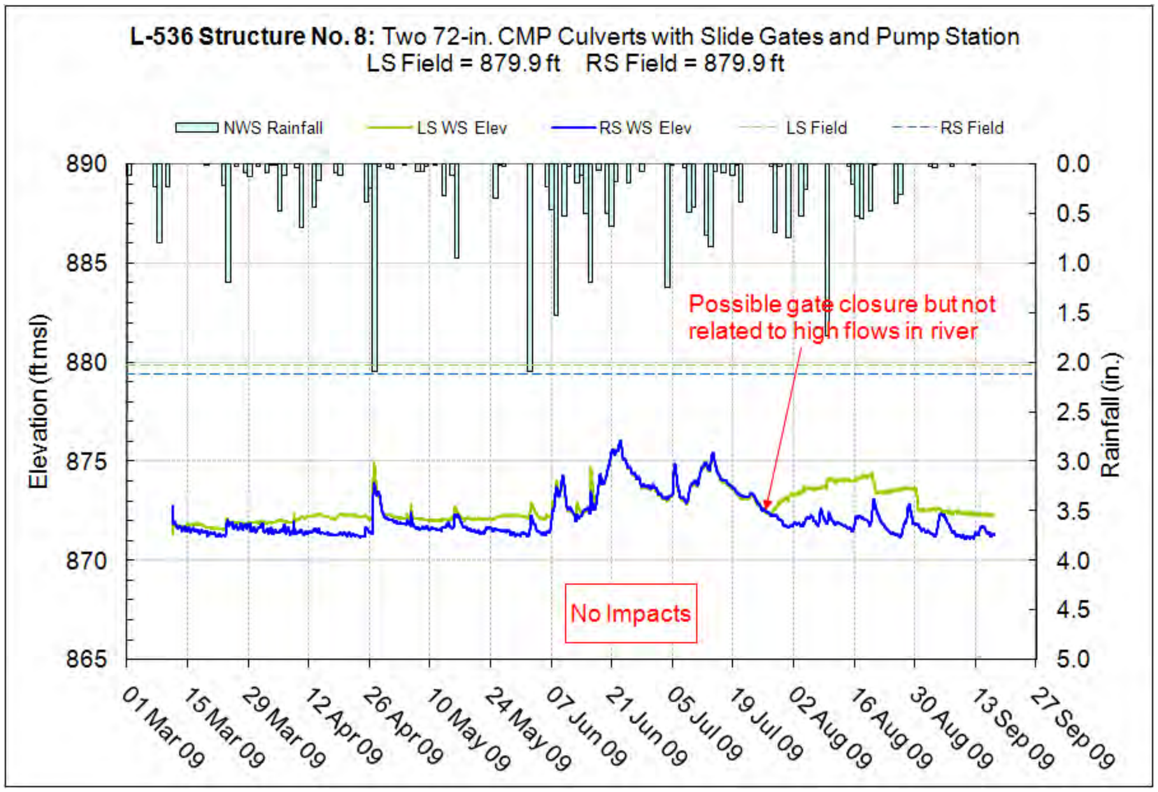

Figure 10.22.7 – NSR socioeconomic impacts, L-536 Structure No. 8

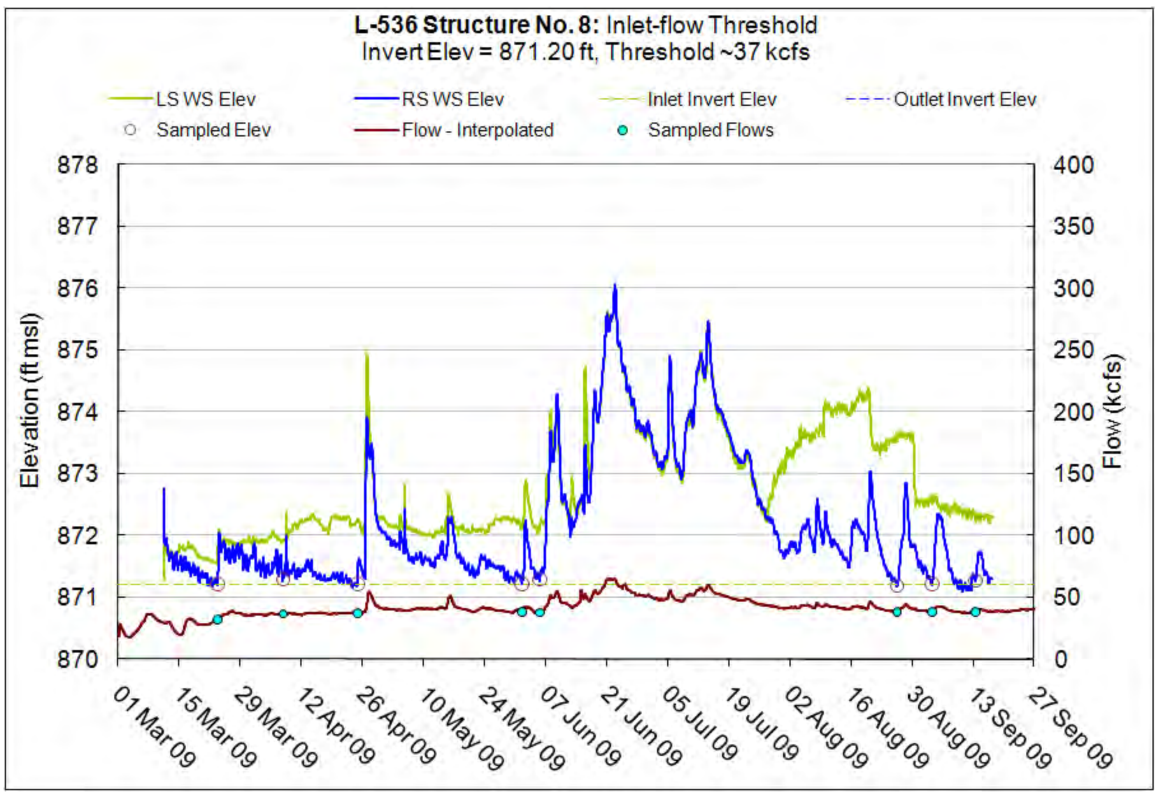

Figure 10.22.8 – Inlet-flow threshold, L-536 Structure No. 8 (2008 record)

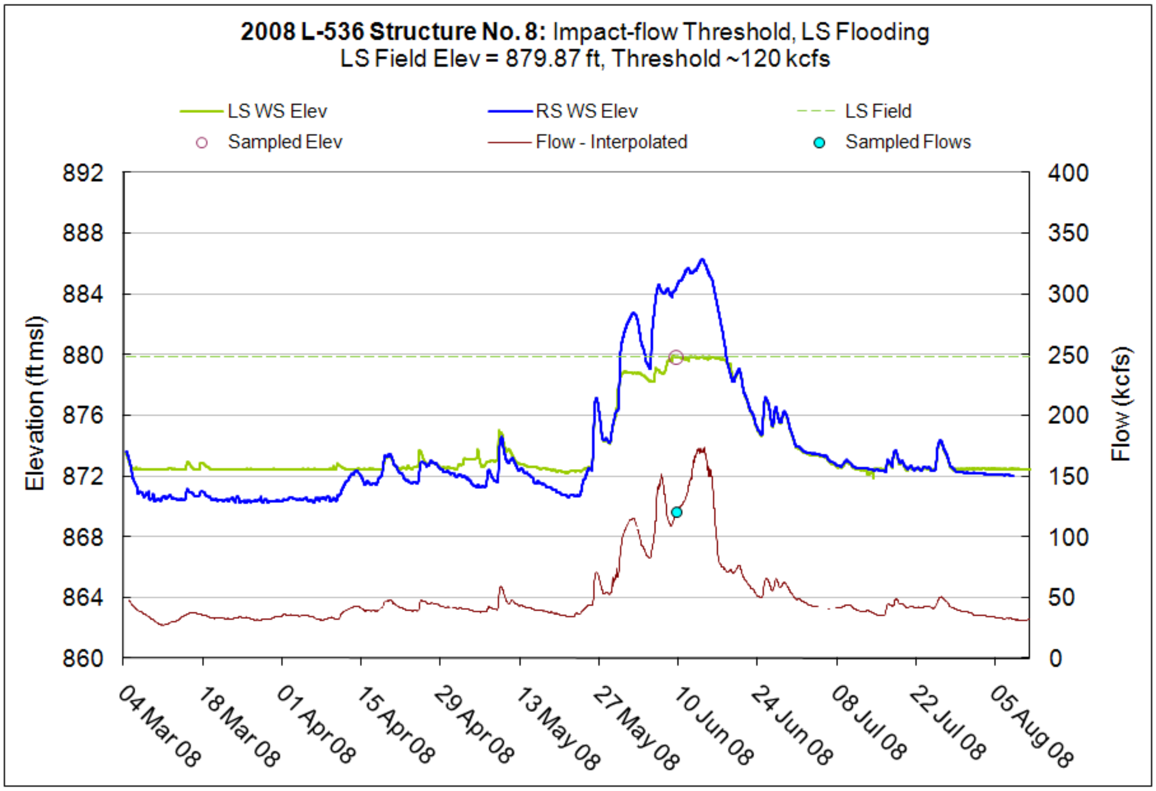

Figure 10.22.9 – Impact-flow threshold (LS flooding), L-536 Structure No. 8 (2008 record)

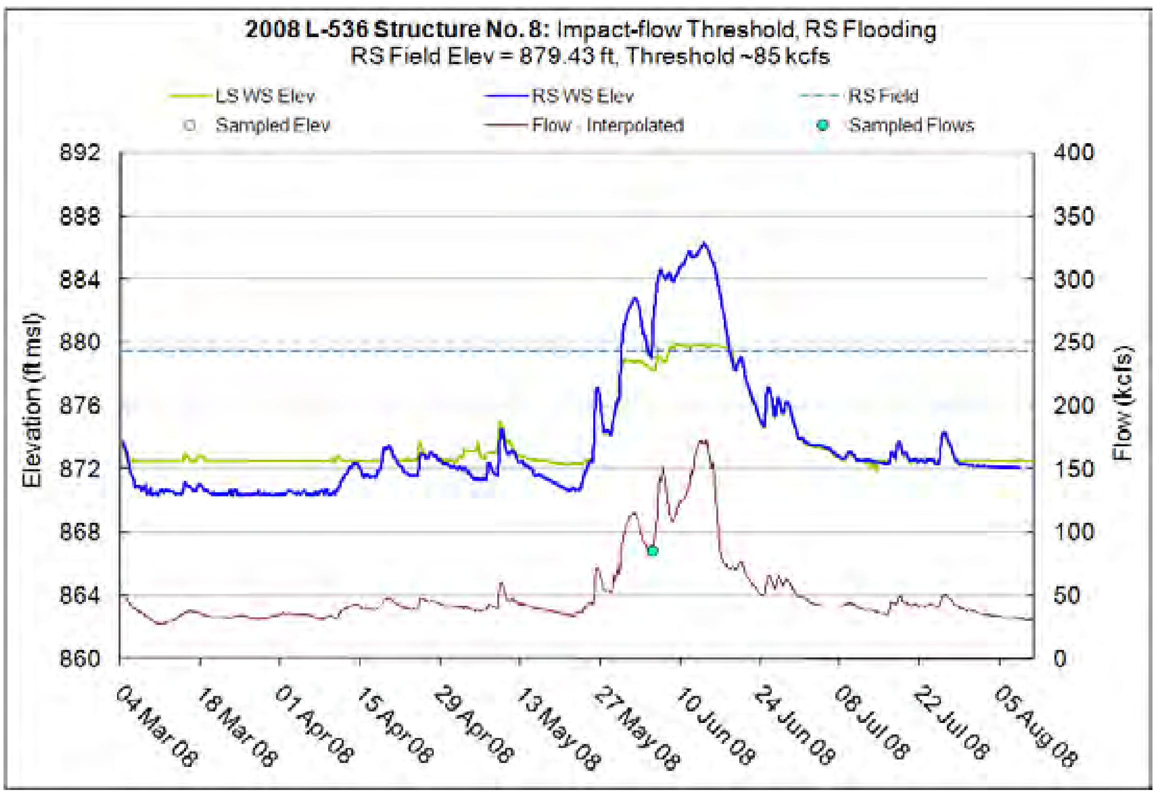

Figure 10.22.10 – Impact-flow threshold (RS flooding), L-536 Structure No. 8 (2008 record)

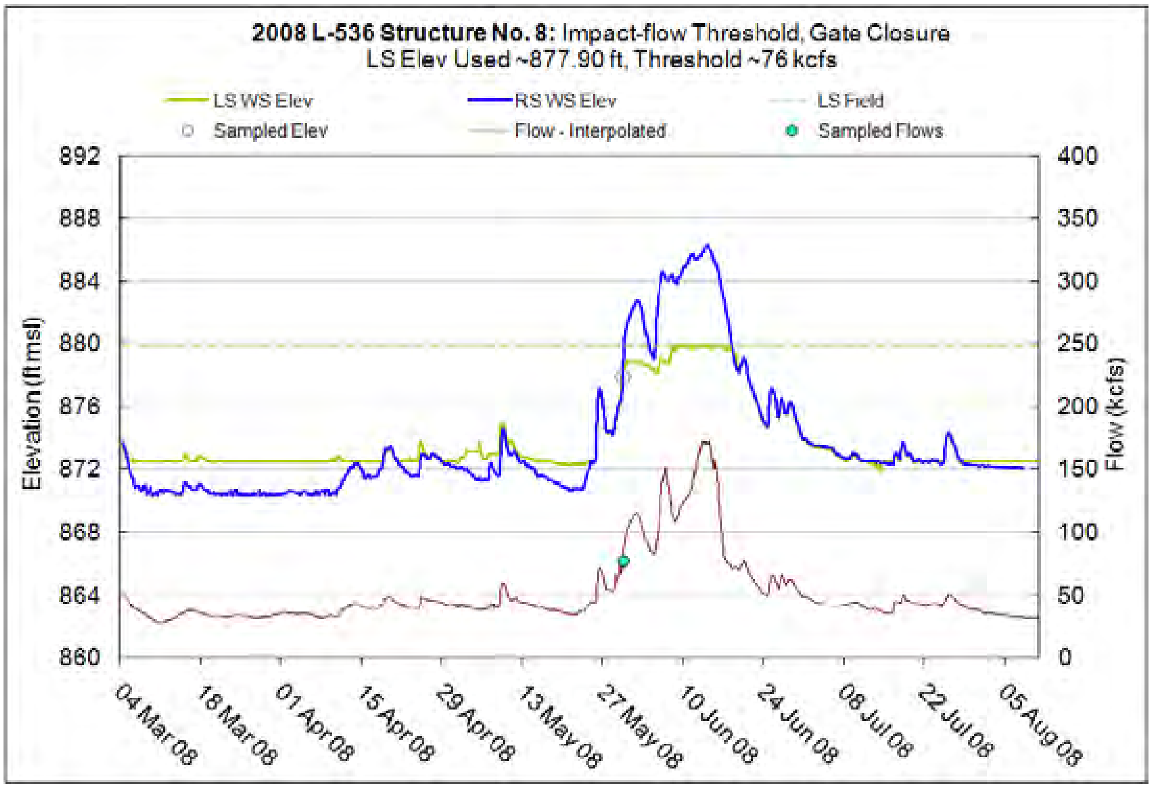

Figure 10.22.11 – L-536 Structure No. 8 impact-flow threshold (gate closure), 2008 record

10.23 USGS Rulo

The USGS Missouri River Rulo gage is located at river mile 498.1 on the right bank of the Missouri River to the east of Rulo, NE (Figure 10.23.1). Figure 10.23.2 shows the created spring rise produced by the spring pulse released from Gavins Point Dam. The created spring rise at this site was approximately 0.6 ft. Figure 10.23.3 shows the full monitoring record with the travel time of the spring pulse noted.

Figure 10.23.1 – USGS Rulo location

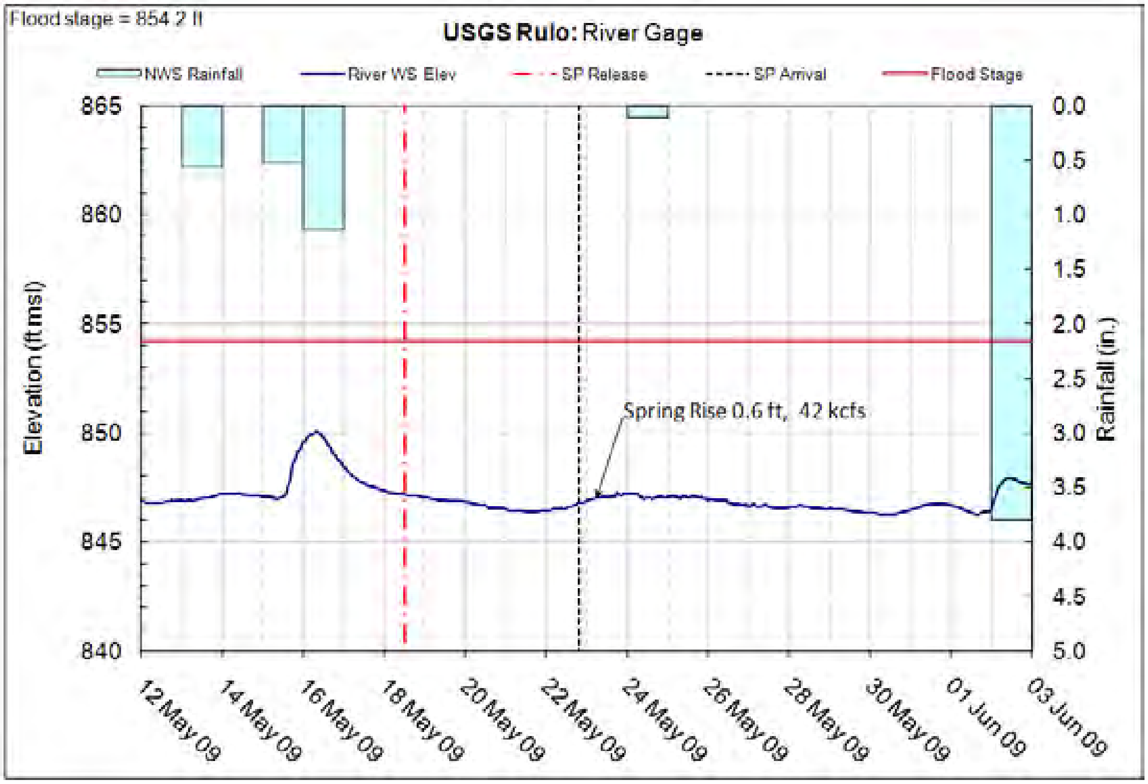

Figure 10.23.2 – Spring rise at USGS Rulo

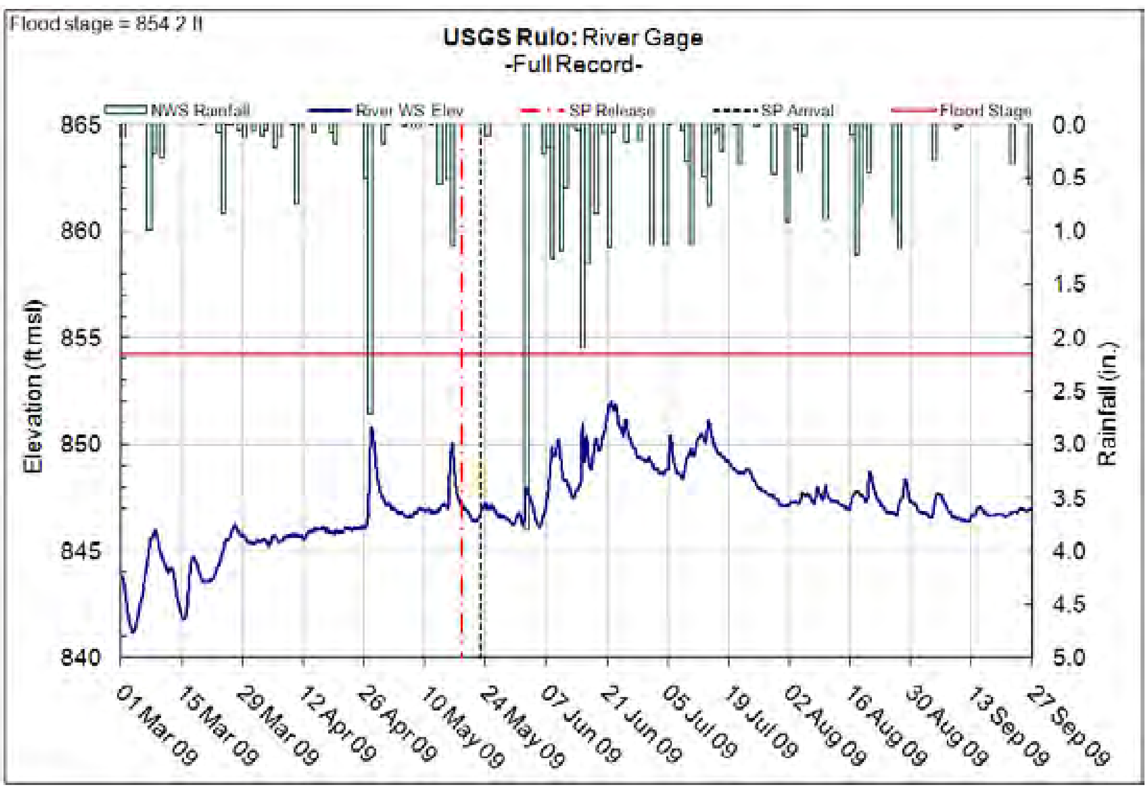

Figure 10.23.3 – Full monitoring record at USGS Rulo

10.24 Holt County LD No. 9

The Holt County LD No. 9 supplemental gage is located at RM 490.8 on the left bank of the Missouri River in Holt County, MO between the Squaw Bend and the White Cloud Bend of the Missouri River (Figure 10.24.1). The drainage structure at the site is a single 36-in. CMP through the main levee with an open inlet and a flap-gated outlet (Figure 10.24.2). The inlet-invert elevation of the culvert is 841.64 ft, and the outlet invert is 841.29 ft. The crest of the levee over the drainage structure is 860.07 ft. The inlet drainage ditch is an excavated ditch and has no berms. The outlet drains directly to the river and the site does not have a pump station. The LS data logger was installed at the culvert inlet, and the RS data logger was installed on the river bank next to the outlet.

Field elevations were surveyed for the 2009 monitoring effort. The average LS field elevation of the fields beyond the right of the drainage ditch is 850.8 ft. The average LS field elevation of the fields beyond the left bank of the drainage ditch is 852.7 ft. The 850.8 ft field elevation was used in the figures and analysis. All elevations are in the NAVD 88 datum. Flows were estimated at the site by lagging the flow records of USGS Rulo and USGS St. Joseph to the site based on peaks and then interpolating flows based on river miles.

Results

- Table 10.24.1 summarizes the results for the May 2009 and March 2008 created spring rises, and the Missouri River flows estimated to reach the outlet and inlet of the site's drainage structure.
- Figure 10.24.3 shows the spring pulse release on May 18 and its arrival time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise created by the spring pulse could not be objectively identified due to the chatter in the record at this site. Based on the attenuation analysis, the spring pulse accounts for 3.2 kcfs of the total 41-kcfs Missouri-River flow at this river mile, or 7.8% of the total flow.
- Figure 10.24.4 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site shown.
- Figure 10.24.5 shows the full period of the monitoring record with the inlet- and the outlet-invert elevation of the drainage structure.
- Figure 10.24.6 shows the lowest 2009 surveyed LS field elevation.
- Figure 10.24.7 shows the estimate of the flow threshold for the outlet invert. The Missouri River has to be over 42 kcfs to reach the outlet invert.
- Figure 10.24.8 shows an estimate of the inlet-invert flow threshold. Because the LS water elevation does not drop below the invert elevation, the threshold was estimated based on the RS elevation dropping below the inlet-invert elevation. The Missouri River has to be over 43 kcfs to reach the inlet-invert elevation.

Conclusions

No socioeconomic impacts were produced at this site by either the created spring rise or natural spring rises in May 2009. The created spring rise could not be separated from background effects on the river. Based on the attenuation analysis, the spring pulse accounts for 3.2 kcfs of the total 41-kcfs Missouri-River flow at this river mile, or 7.8% of the total flow.

Table 10.24.1 – Holt County LD No. 9 results

Spring Pulse from Gavins Point Dam		
	May-09	***Mar-08***
Created spring rise, ft	n.a.[1]	-
Estimated created spring rise flow, kcfs	3.2	-
Estimated MR flow, kcfs	41	-
% of MR flow	7.8	-

Outlet-flow Threshold		
	May-09	***Mar-08***
Elev, ft	841.29	841.29
Estimated flow at site, kcfs	43	-
Flow at nearest US gage, kcfs	42	-
Nearest US gage	Rulo	-

Inlet-flow threshold		
	May-09	***Mar-08***
Elev, ft	841.64	841.64
Estimated flow at site, kcfs	43	-
Flow at nearest US gage, kcfs	42	-
Nearest US gage	Rulo	-

Impacts

No observed socioeconomic impacts.

[1]The created spring rise could not be objectively measured due to chatter in stage record.

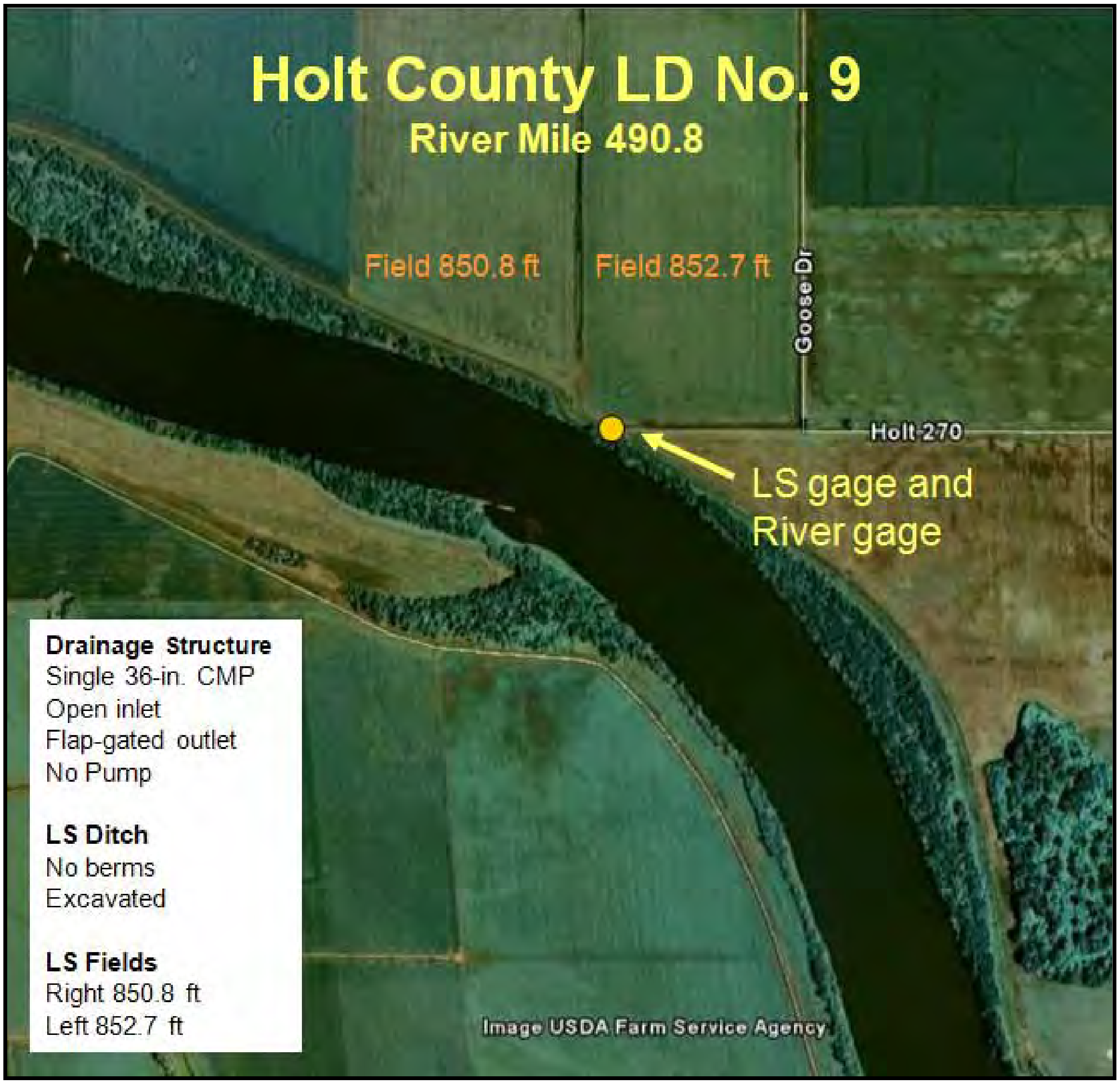

Figure 10.24.1 – Holt County LD No. 9 location

Figure 10.24.2 – Holt County LD No. 9 site and gages. Upstream culvert gage at inlet of 36-in. CMP (upper left). River gage (upper right). Flap-gated outlet on river (lower left). Inlet ditch and interior fields (lower right).

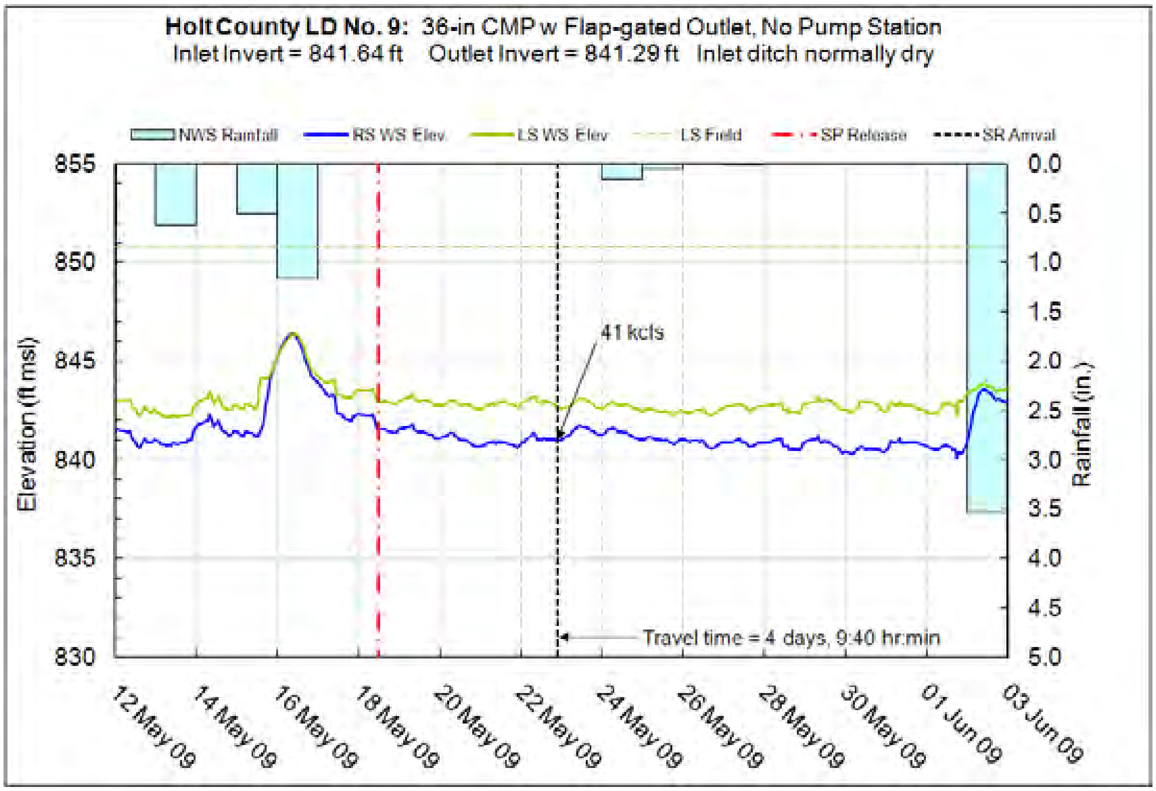

Figure 10.24.3 – Spring rise at Holt County LD No. 9

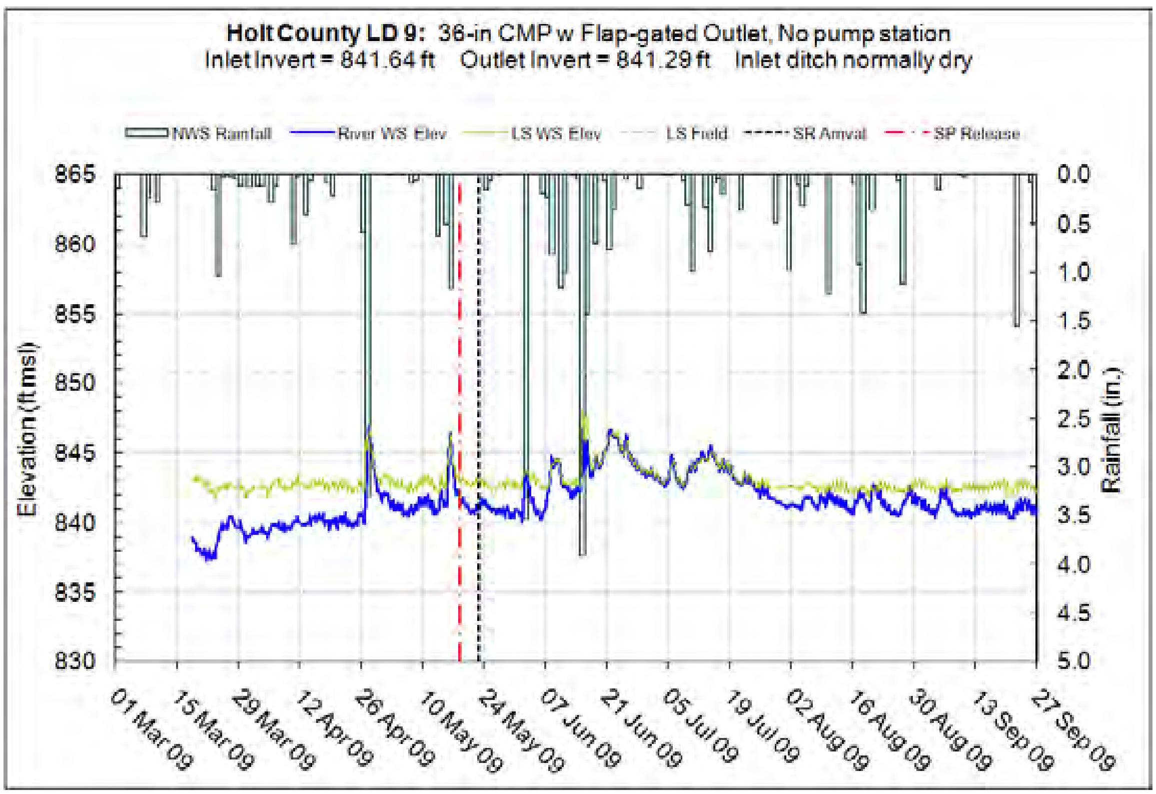

Figure 10.24.4 – Full monitoring record at Holt County LD No. 9

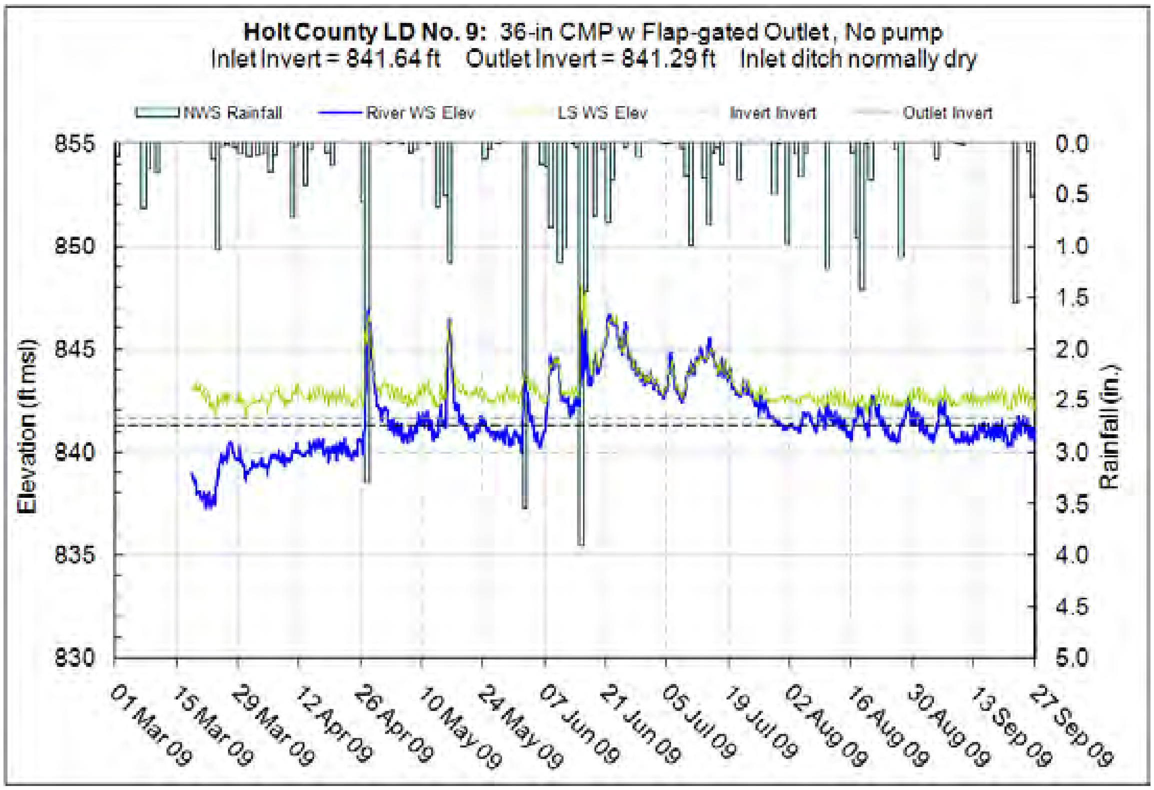

Figure 10.24.5 – Invert elevations, Holt County LD No. 9

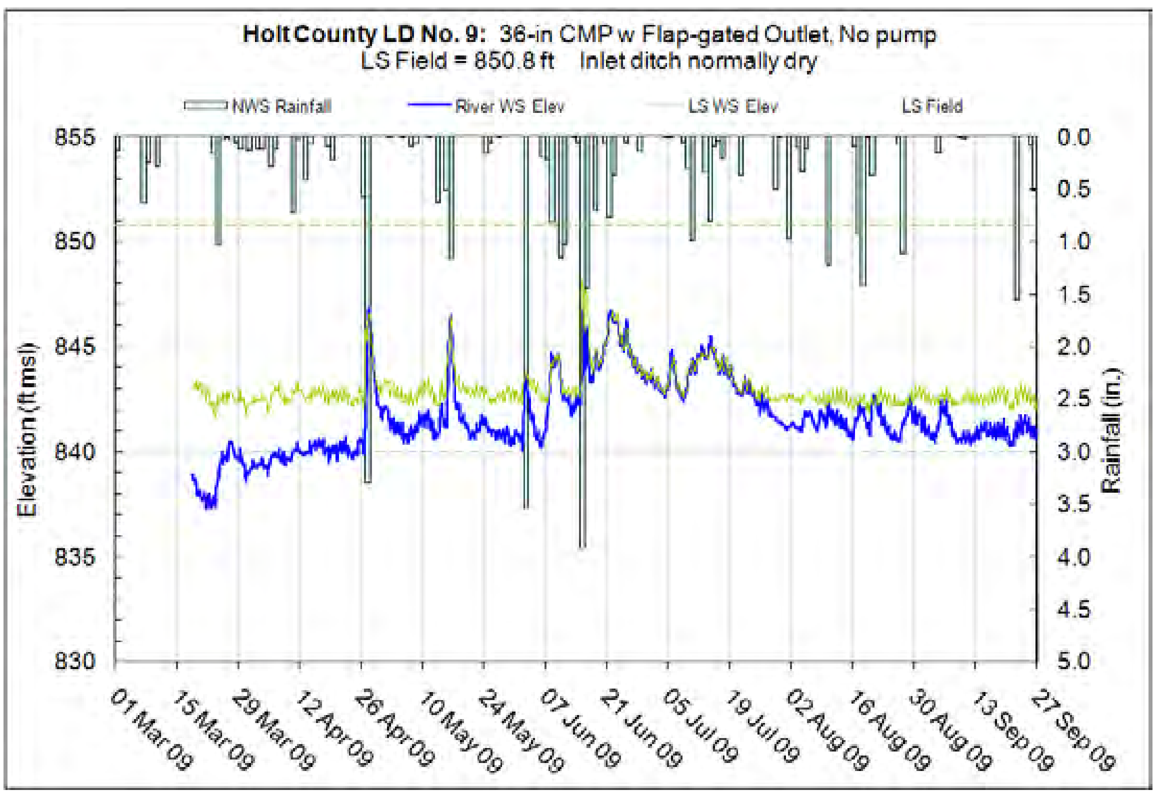

Figure 10.24.6 – Surveyed field elevations, Holt County LD No. 9

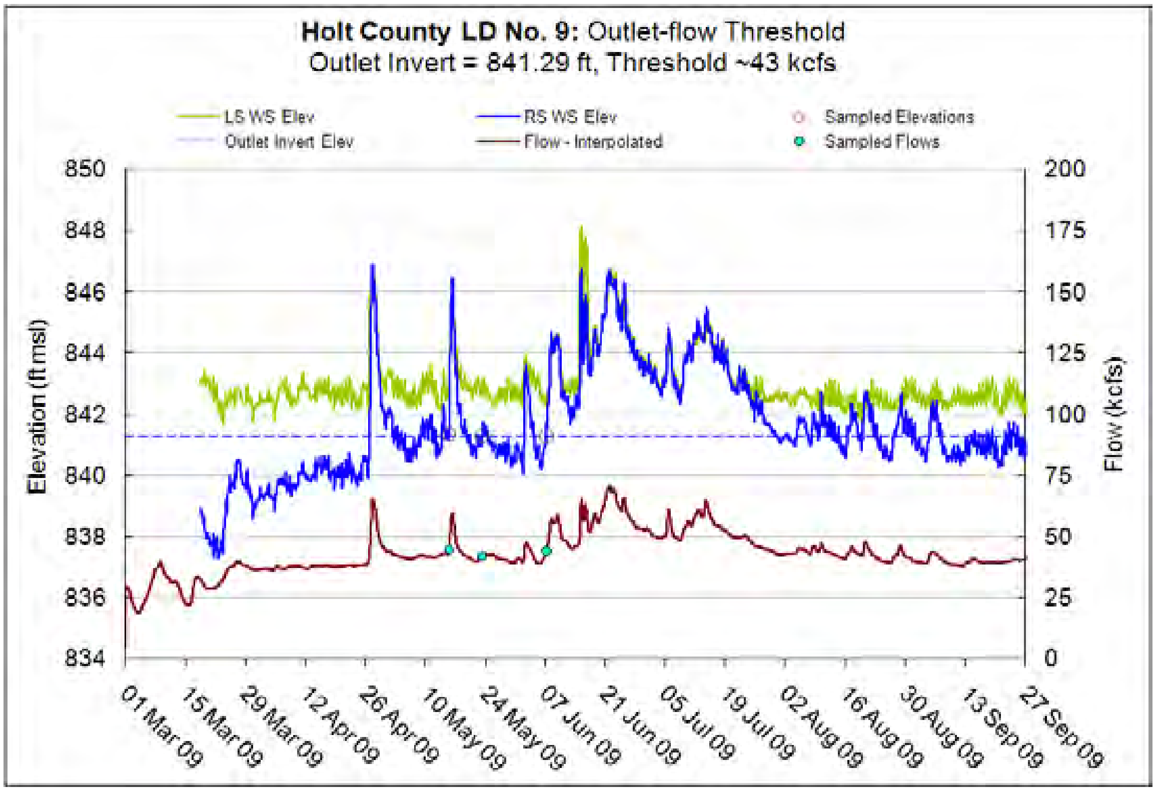

Figure 10.24.7 – Outlet-flow threshold, Holt County LD No. 9

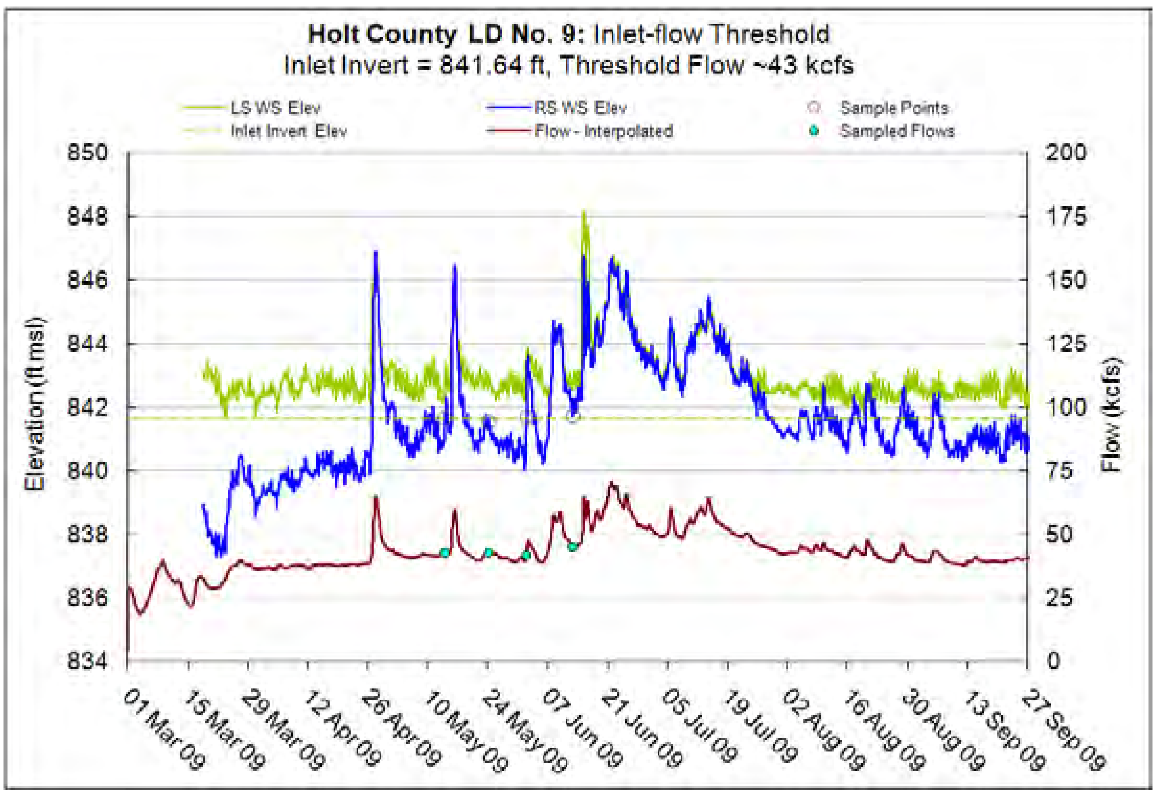

Figure 10.24.8 – Inlet-flow threshold, Holt County LD No. 9

10.25 R-500

The R-500 supplemental gage is located at RM 480.2 on the west bank of the Missouri River in the US portion of Wolf Creek bend in Doniphan County, KS (Figure 10.25.1). The drainage structure at this site consists of three 60-in. CMPs through the main levee at the main drainage ditch (Figure 10.25.2, top). The inlet invert elevation of the middle drainage structure is 833.13 ft and the inlet ditch is not gated. The outlet invert elevation is 831.16 ft and the outlets have slide gates in the concrete outlet structure. The outlet ditch riverward of the levee extends 0.3 miles to the Missouri River. The site has a mobile pump.

The LS data logger was installed about 200 ft US of the structure in the inlet ditch (Figure 10.25.3, left). A river data logger was not installed. The RS water surface elevations are those of the L-497 Main Outfall DCP 3.1 RM downstream with an added elevation of 3.12 ft to account for differences in the elevations (Figure 10.25.3, right). The 3.12 ft difference in river elevations from the L-497 Main Outfall DCP to the site is based on differences in the CRP elevations (typical moderate flow profile) for the two sites. Field elevations were surveyed for the 2009 monitoring. The field elevations on both sides of the levee are at similar elevations. The survey field elevation of 841.2 ft used in the figures was taken about 200 ft inside the levee. The site has a berm of the right bank of the inlet ditch, but it is a soil pile and not effective. Elevations are in the NAVD 88 datum. Flows were estimated at the site by lagging the flow records of USGS Rulo and USGS St. Joseph to the site based on peaks and then interpolating flows based on river miles.

Results

§ Table 10.25.1 summarizes the results for the May 2009 created spring rise, and the Missouri River flows estimated to reach the outlet and inlet of the site's drainage structure.

§ Figure 10.25.4 shows the spring pulse release on May 18 and its arrival time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise created by the spring pulse was 0.5 ft. Based on the attenuation analysis, the spring pulse accounts for 3.1 kcfs of the total 43 kcfs Missouri River flow at this river mile, or 7.2% of the total flow.

§ Figure 10.25.5 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site shown.

§ Figure 10.25.6 shows the full monitoring record with the inlet and the outlet invert elevation of the drainage structure

§ Figure 10.25.7 shows the 2009 surveyed field elevation for the LS fields. No socioeconomic impacts were identified at this site during the 2009 monitoring period.

§ Figure 10.25.8 shows the estimation of the outlet-invert flow threshold. The estimated threshold flow in the Missouri River required to reach the outlet-invert elevation of the site is 48 kcfs.

§ Figure 10.25.9 shows the estimation of the inlet-flow threshold. The estimated threshold flow in the Missouri River required to reach the inlet-invert elevation of the site is 58 kcfs.

Conclusions

No socioeconomic impacts were created by either the created or natural spring rises during the 2009 monitoring period at this site. Based on the attenuation analysis, the spring

pulse accounts for 3.1 kcfs of the total 43-kcfs Missouri River flow at this river mile, or 7.2% of the total flow.

Table 10.23.1 – R-500 results

Spring Pulse from Gavins Point Dam		
	May-09	***Mar-08***
Created spring rise, ft	0.5	-
Estimated created spring rise flow, kcfs	3.1	-
Estimated MR flow, kcfs	43	-
% of MR flow	7.2	-
Outlet-flow Threshold		
	May-09	***Mar-08***
Elev, ft	831.16	-
Estimated flow at site, kcfs	48	-
Flow at nearest US gage, kcfs	45	-
Nearest US gage	Rulo	-
Inlet-flow threshold		
	May-09	***Mar-08***
Elev, ft	833.13	-
Estimated flow at site, kcfs	58	-
Flow at nearest US gage, kcfs	53	-
Nearest US gage	Rulo	-
Impacts		
No observed socioeconomic impacts.		

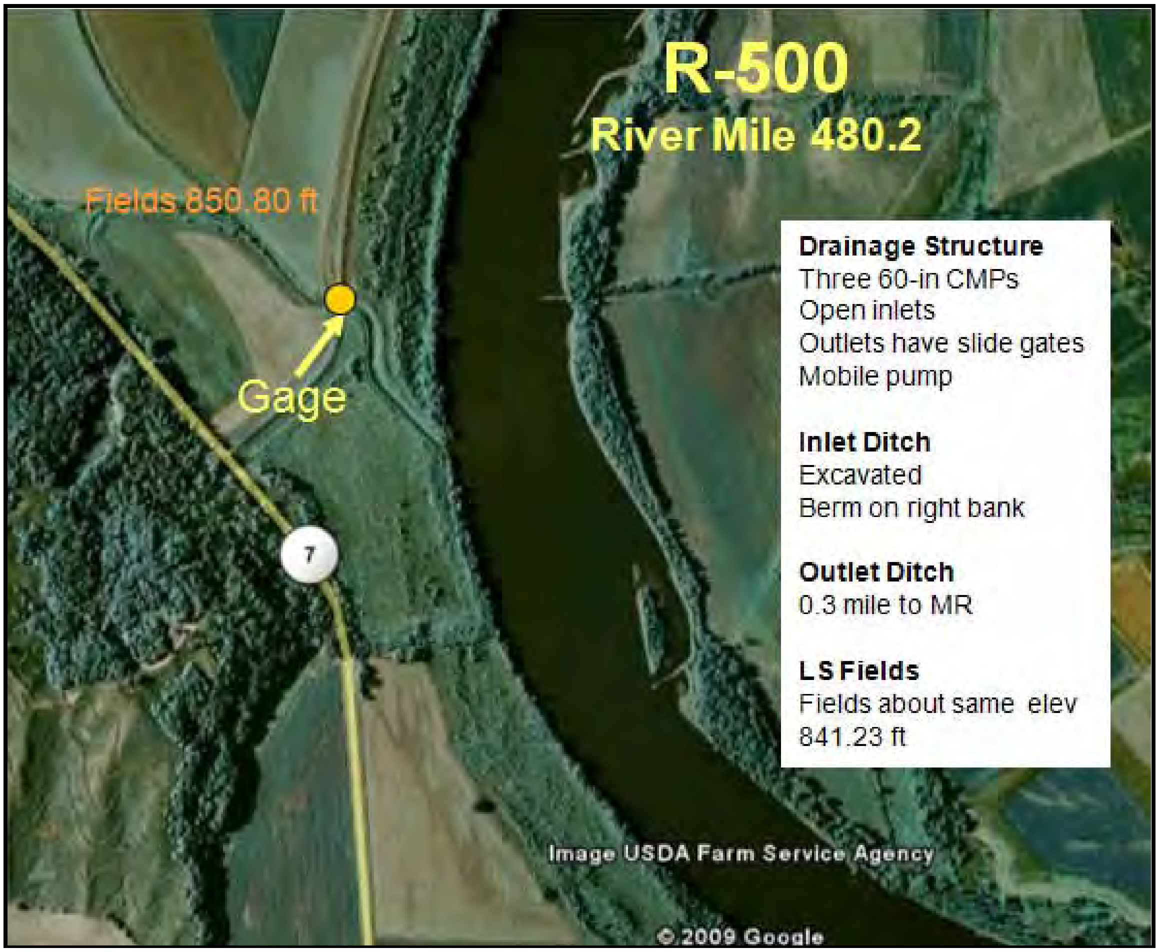

Figure 10.25.1 – R-500 location

Figure 10.25.2 – R-500 site. Main outfall gate structure with screw-gated outlets (top left). Three 60-in. CMPs through main levee (top right). Main outfall gate structure and outlet ditch to river (bottom left). Inlet ditch of main outfall and fields (bottom right).

Figure 10.25.3 – R-500 gages. Landside data logger (left). Riverside DCP at L-497 3.1 RM downstream of R-500 (right).

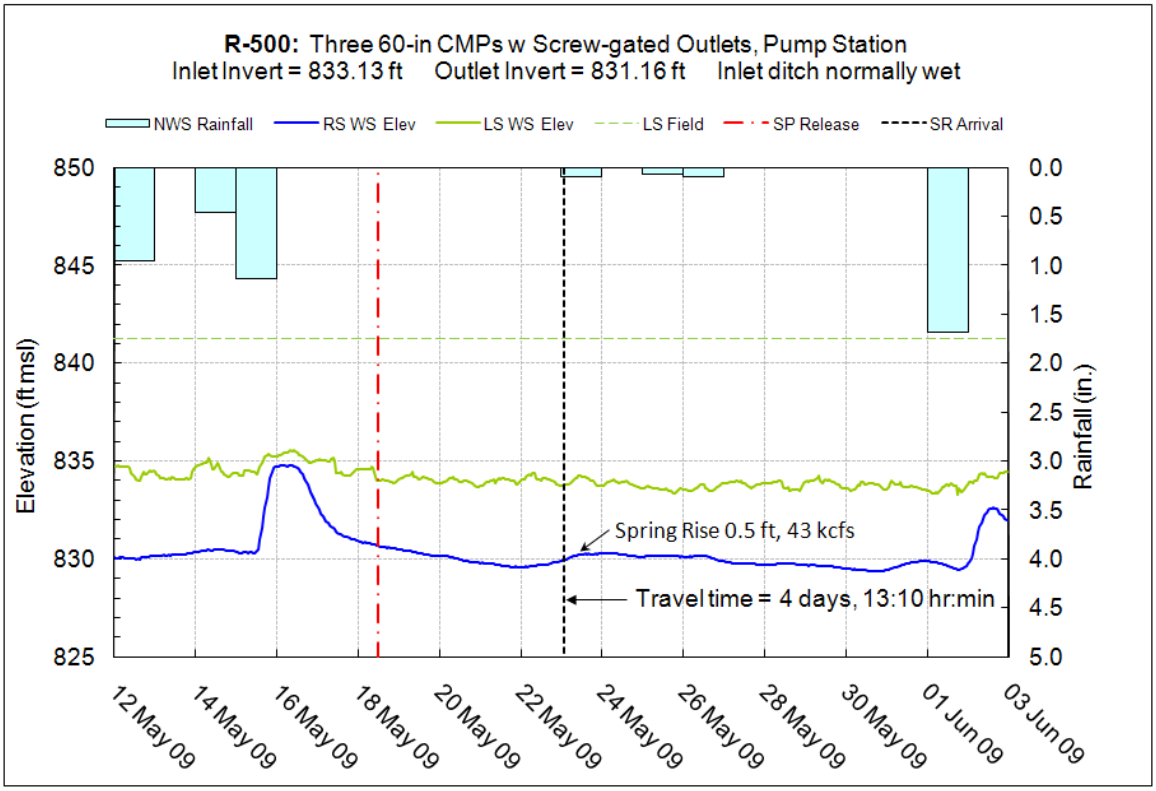

Figure 10.25.4 – Spring rise at R-500

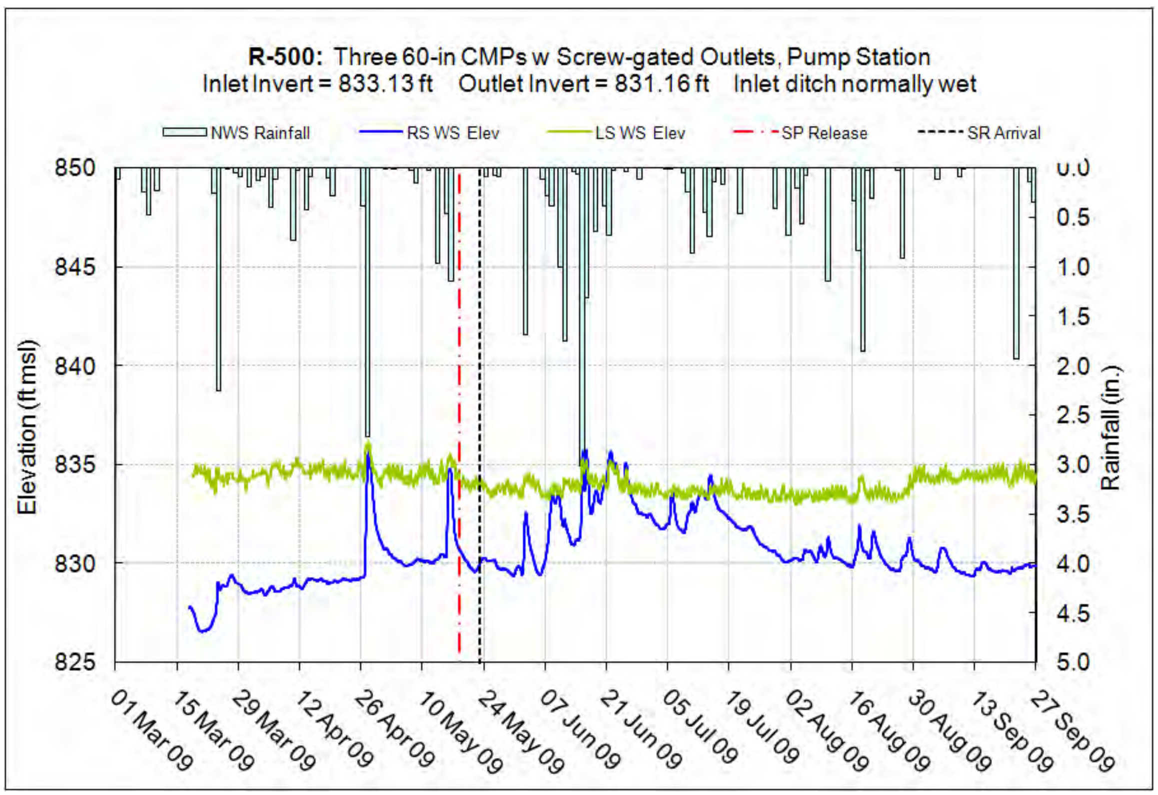

Figure 10.25.5 – Full monitoring record at R-500

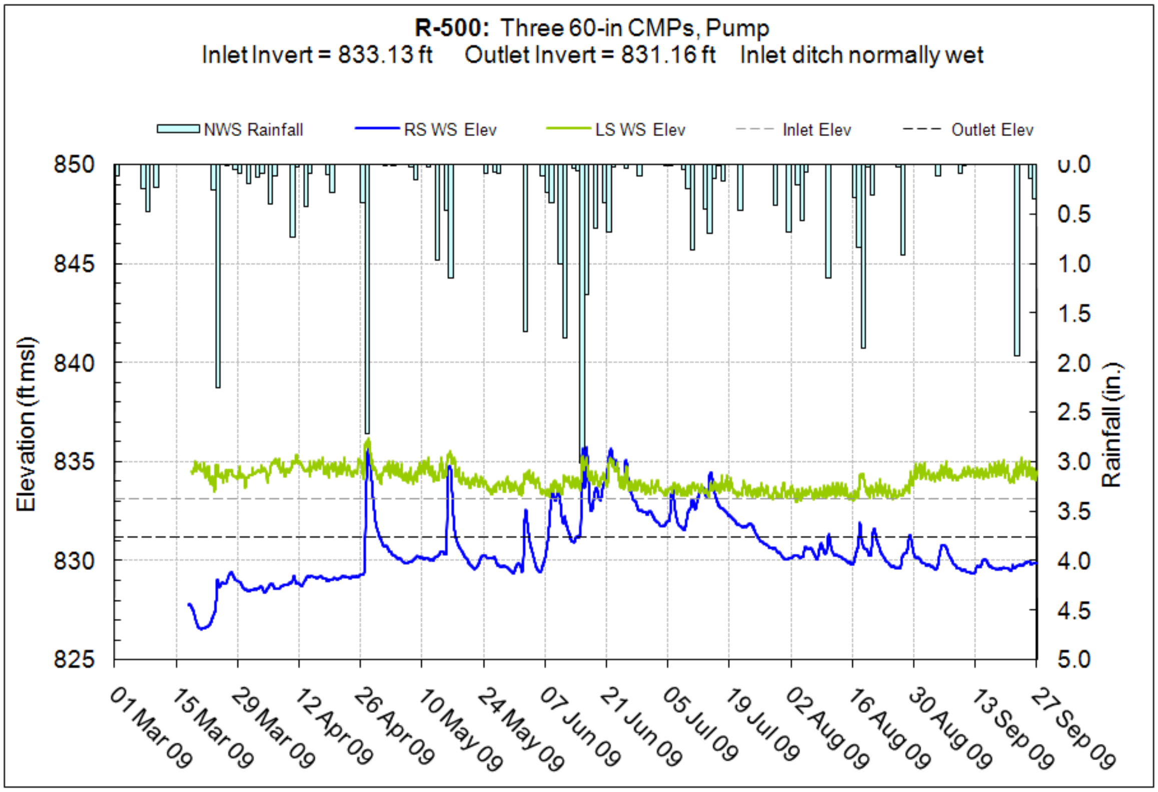

Figure 10.25.6 – Inlet elevations, R-500

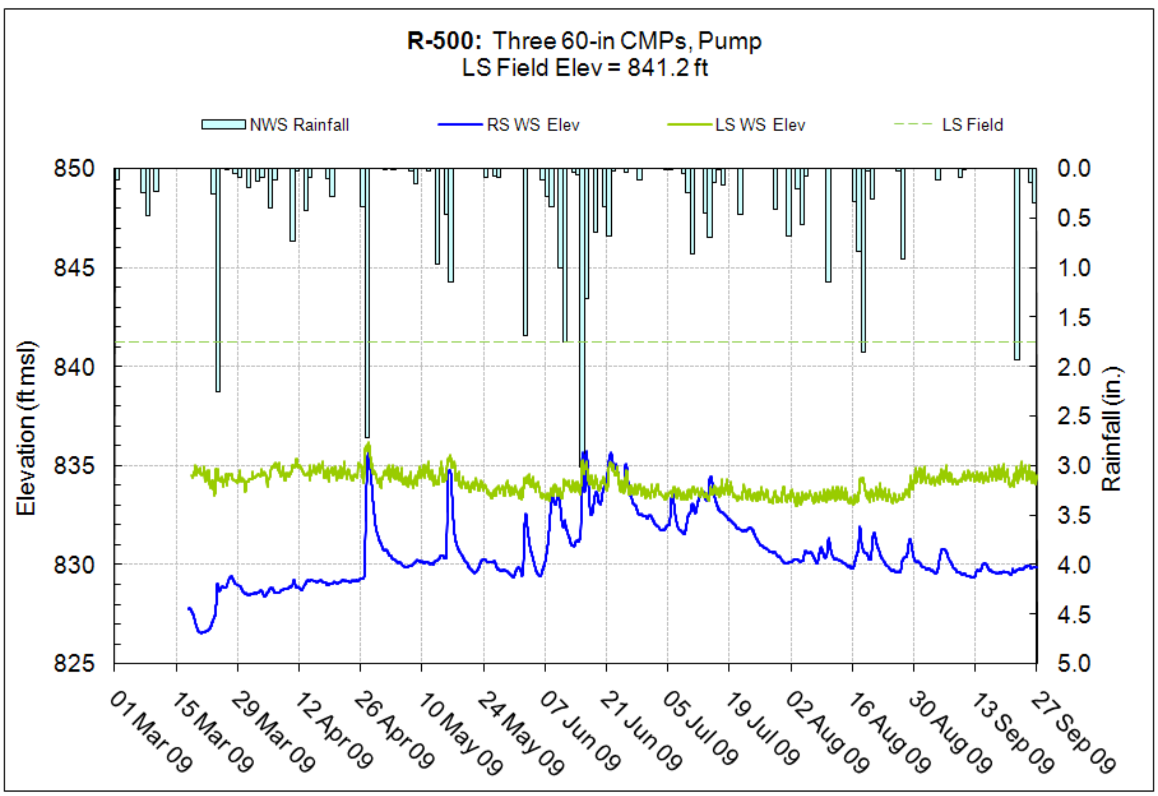

Figure 10.25.7 – Surveyed field elevations, R-500

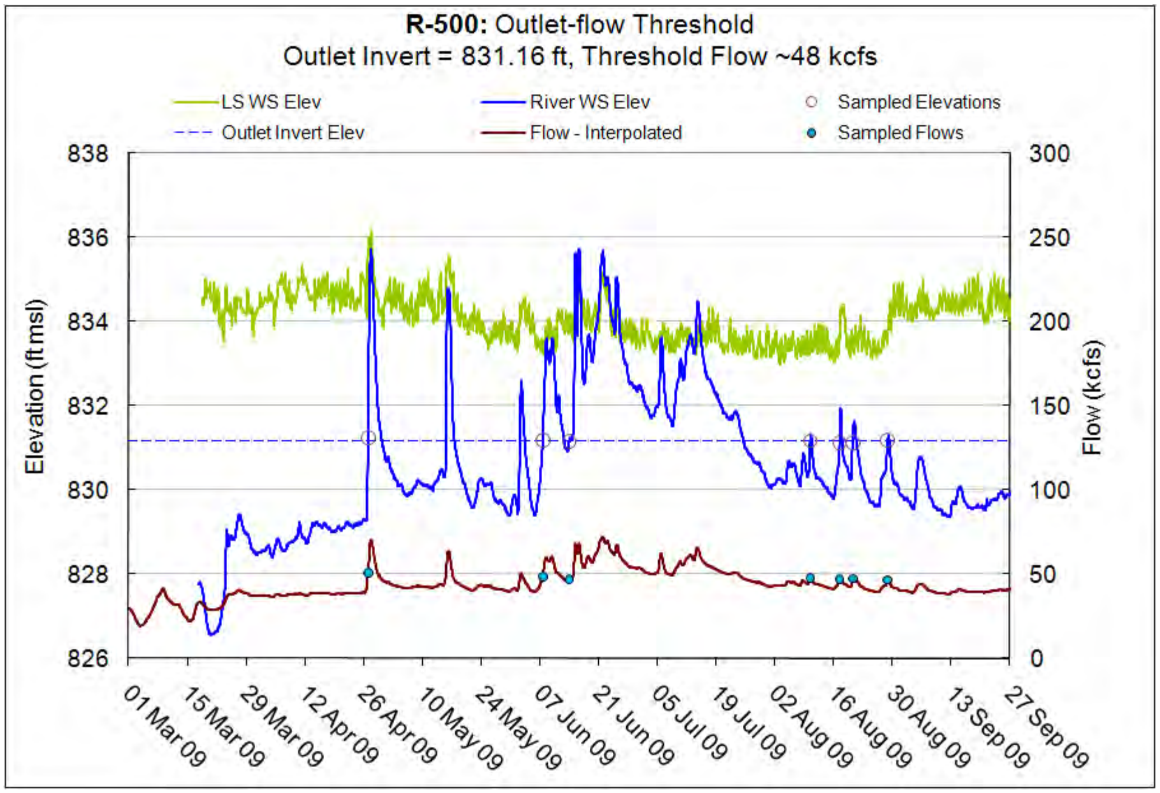

Figure 10.25.8 – Outlet-flow threshold, R-500

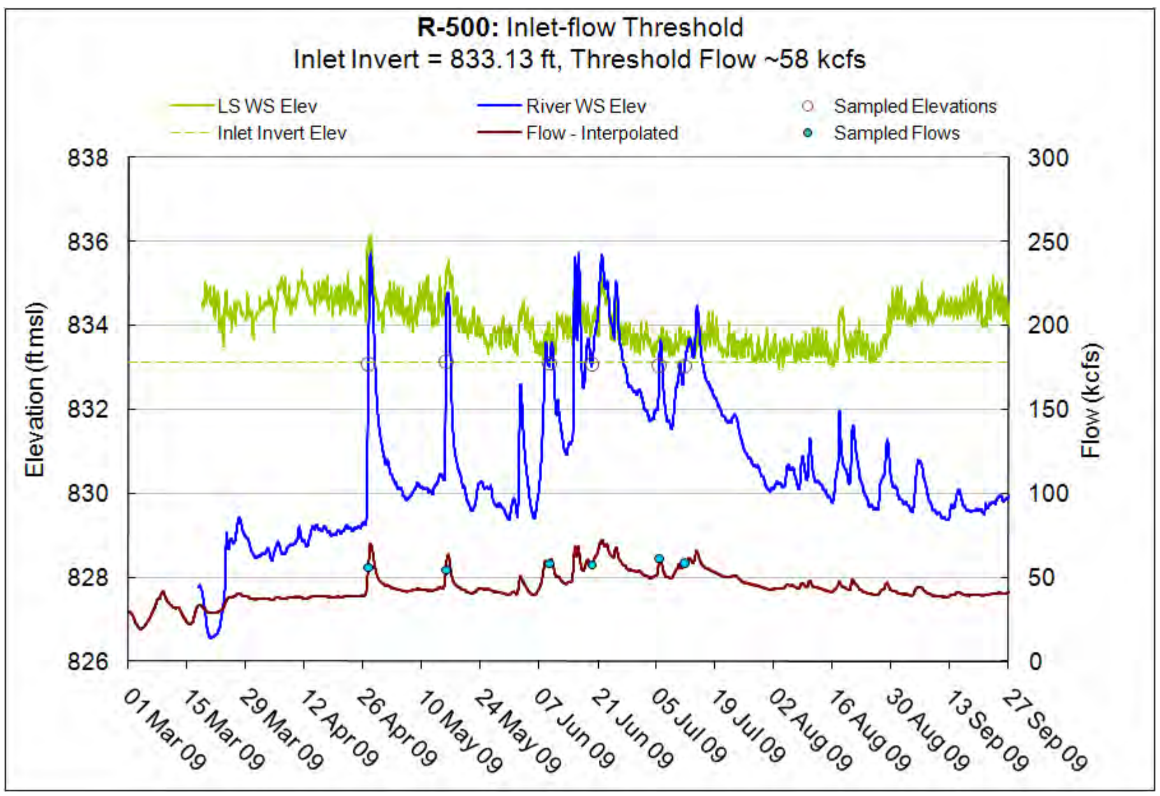

Figure 10.25.9 – Inlet-flow threshold, R-500

10.26 L-497 Main Outfall

The L-497 Main Outfall gage is located on the left bank at river mile 477.1 north of Lookout Mountain and about 5 miles southeast of Forest City, MO (Figure 10.26.1). The drainage structure at this site has three 60-in. CMPs with slide-gated outlets and one 135-HP diesel pump. Invert elevations were resurveyed in 2009. The lowest culvert's inlet elevation is 830.73 ft (msl), its outlet elevation is also 830.73 ft (msl), and the elevation of the top of the levee above the culverts is 854.08 ft (msl). Figure 10.24.2 shows the inlet and outlet of the site.

A drainage ditch 616 ft in length connects the culverts' outlets with the Missouri River. The inlet ditch has berms on either side of the ditch. The access road to the Paynes Landing boat ramp runs along the top of the left bank berm (Figure 10.26.2 bottom left). Field elevations were surveyed in 2009. The surveyed LS average field elevation beyond the right bank of the inlet ditch and near the tieback berm is 835.6 ft. The field elevation beyond the left bank of the inlet ditch is 834.7 ft. The elevation of the crest of the tieback berm along the right bank of the inlet ditch is 841.9 ft. The elevation of the crest of the access road along the left bank berm is 841.2 ft. The lowest berm elevation and the LS field elevation protected by the berm are shown in the figures and used in the analysis. Elevations are in the NAVD 88 datum.

Two gages were installed at this location in 2008. The RS gage was located near the outlet of the three culverts, and the LS gage is located in the ponding area upstream of the culverts. The RS gage was replaced with the DCP on the river for the 2009 monitoring period. Figure 10.24.3 shows the LS data logger (left) and river DCP (right). Flows were estimated at the site by lagging the flow records of USGS Rulo and USGS St. Joseph to the site based on peaks and then interpolating flows based on river miles.

Results

- Table 10.26.1 summarizes the results for the May 2009 and March 2008 created spring rises, and the Missouri River flows estimated to reach the outlet and inlet of the site's drainage structure.
- Table 10.26.2 summarizes the socioeconomic impacts produced by the natural spring rises at the site in May 2009 and March 2008.
- Figure 10.26.4 shows the spring pulse release on May 18 and its arrival time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise created by the spring pulse was 0.5 ft. Based on the attenuation analysis, the spring pulse accounts for 3.0 kcfs of the total 43 kcfs Missouri River flow at this river mile, or 7.0% of the total flow.
- Figure 10.26.5 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site shown. It is important to note that rises on the LS of the structure can be created by more than the Missouri River rising on the RS of the structure. In the case of this site, runoff into the drainage ditch created the LS water surface elevations to rise above the RS elevations in several instances.
- Figure 10.26.6 shows the full monitoring record with the inlet and the outlet invert elevation of the drainage structure.
- Figure 10.26.7 shows the 2009 surveyed field elevations for the RS and LS fields. Water surface elevations did not become high enough to create socioeconomic impacts during the 2009 monitoring record at this site.

- Figures 10.26.8 and 10.26.9 show the estimation of the outlet and inlet-flow thresholds. The estimated threshold flow in the Missouri River required to reach both the outlet and inlet invert elevations of the site is 62 kcfs at the site or 58 at Rulo.
- Figure 10.26.10 shows the estimation of the Missouri River flow at the site when the gate closed in 2008. No gate closures appear to have occurred during the 2009 monitoring record.
- Figure 10.26.11 and 10.26.12 show the estimation of the outlet and inlet invert flow thresholds using the 2008 monitored data. The estimated threshold flow in the Missouri River required to reach the outlet and inlet invert elevations of the site using the 2008 data is 52 kcfs at the site and 51 kcfs at Rulo.

Conclusions

No socioeconomic impacts were created at this site by either the created spring rise or natural spring rises in May 2009. The rise created by the spring pulse was 0.7 ft. Based on the attenuation analysis, the spring pulse accounts for 3.0 kcfs of the total 43-kcfs Missouri River flow at this river mile, or 7.0% of the total flow.

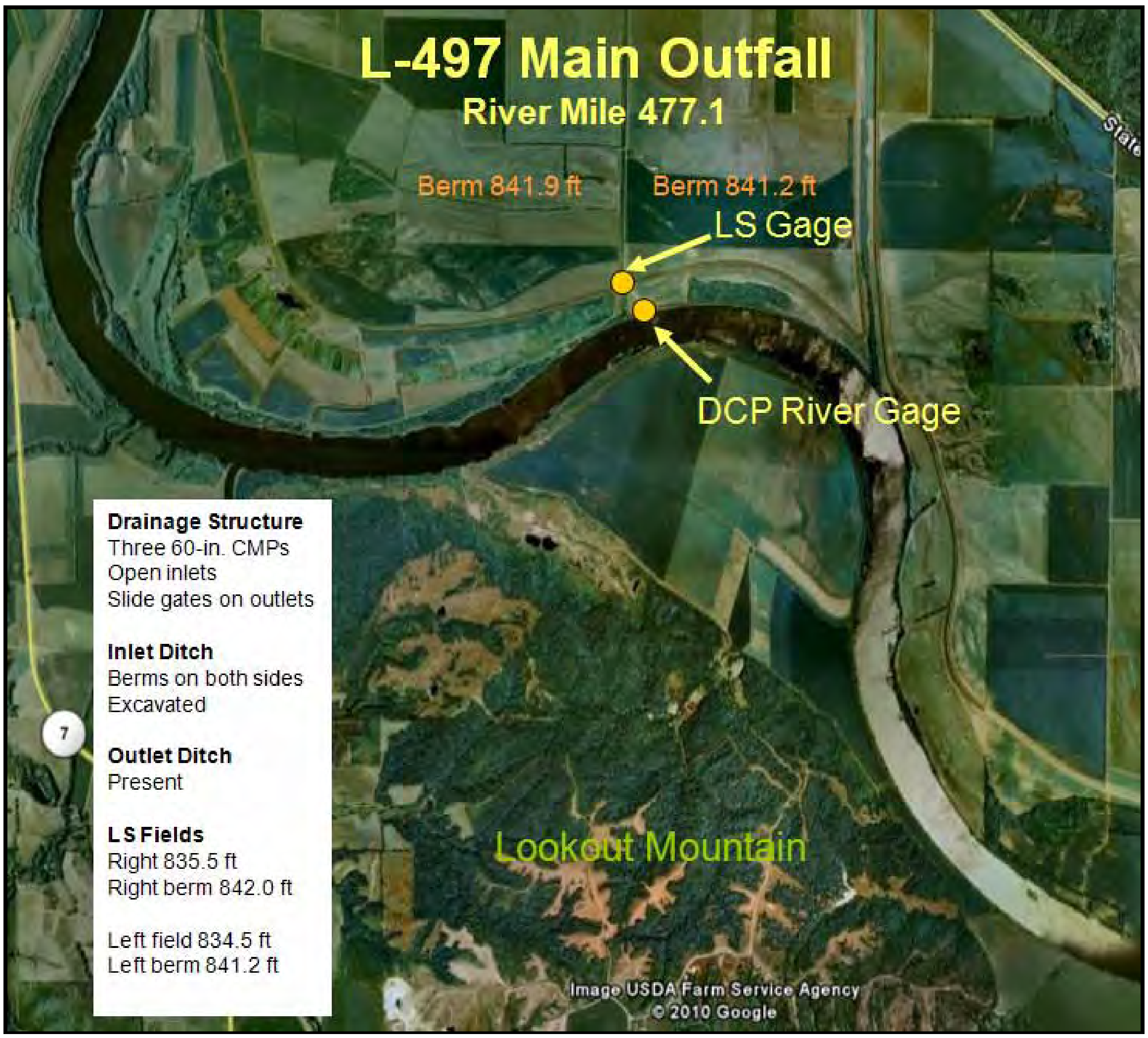

Figure 10.26.1 – L-497 Main Outfall location

Figure 10.26.2 – L-497 Main Outfall site. Culvert inlet with three 60-in. CMPs, pump station, and landside data logger (top left). Concrete outlet gate structure with screw gates (top right). Top of levee looking landward (bottom left). Top of levee looking riverward (bottom right).

Figure 10.26.3 – L-497 Main Outfall gages. Landside gage (left) and river DCP (right).

Table 10.26.1 – L-497 Main Outfall results

Spring Pulse from Gavins Point Dam

	May-09	*Mar-08*
Created spring rise, ft	0.5	n.a.
Estimated created spring rise flow, kcfs	3.0	0.9
Estimated MR flow, kcfs	43	35
% of MR flow	7.0	2.5

Outlet-flow Threshold

	May-09	*Mar-08*
Elev, ft	830.74	830.74
Estimated flow at site, kcfs	62	52
Flow at nearest US gage, kcfs	58	51
Nearest US gage	Rulo	Rulo

Inlet-flow threshold

	May-09	*Mar-08*
Elev, ft	830.73 -> 830.74	830.73 -> 830.74
Estimated flow at site, kcfs	62	52
Flow at nearest US gage, kcfs	58	51
Nearest US gage	Rulo	Rulo

Table 10.26.2 – L-497 Main Outfall NSR socioeconomic impacts

2009 Natural Spring Rise Impacts

	LS Flooding	*Pumping*	*Gate Closure*
Elev, ft	841.2	-	-
Impact duration, dy	No flooding	No pumping	No gate closures
Estimated flow at site, kcfs	n.a.	n.a.	n.a.
Flow at nearest US gage, kcfs	n.a.	n.a.	n.a.
Nearest US gage	Rulo	Rulo	Rulo

2008 Natural Spring Rise Impacts

	LS Flooding	*Pumping*	*Gate Closure*
Elev, ft	841.2	-	-
Impact duration, dy	No flooding	16	16
Estimated flow at site, kcfs	n.a.	71	71
Flow at nearest US gage, kcfs	n.a.	69	69
Nearest US gage	Rulo	Rulo	Rulo

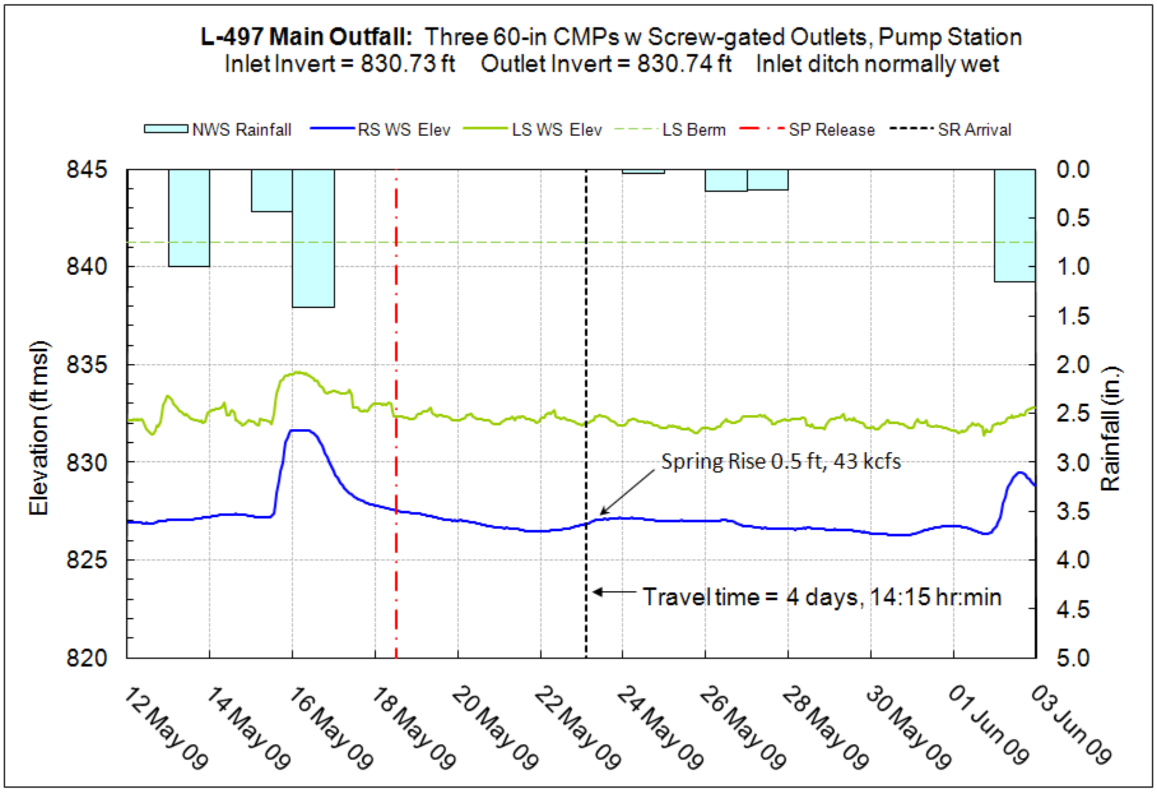

Figure 10.26.4 – Spring rise at L-497 Main Outfall

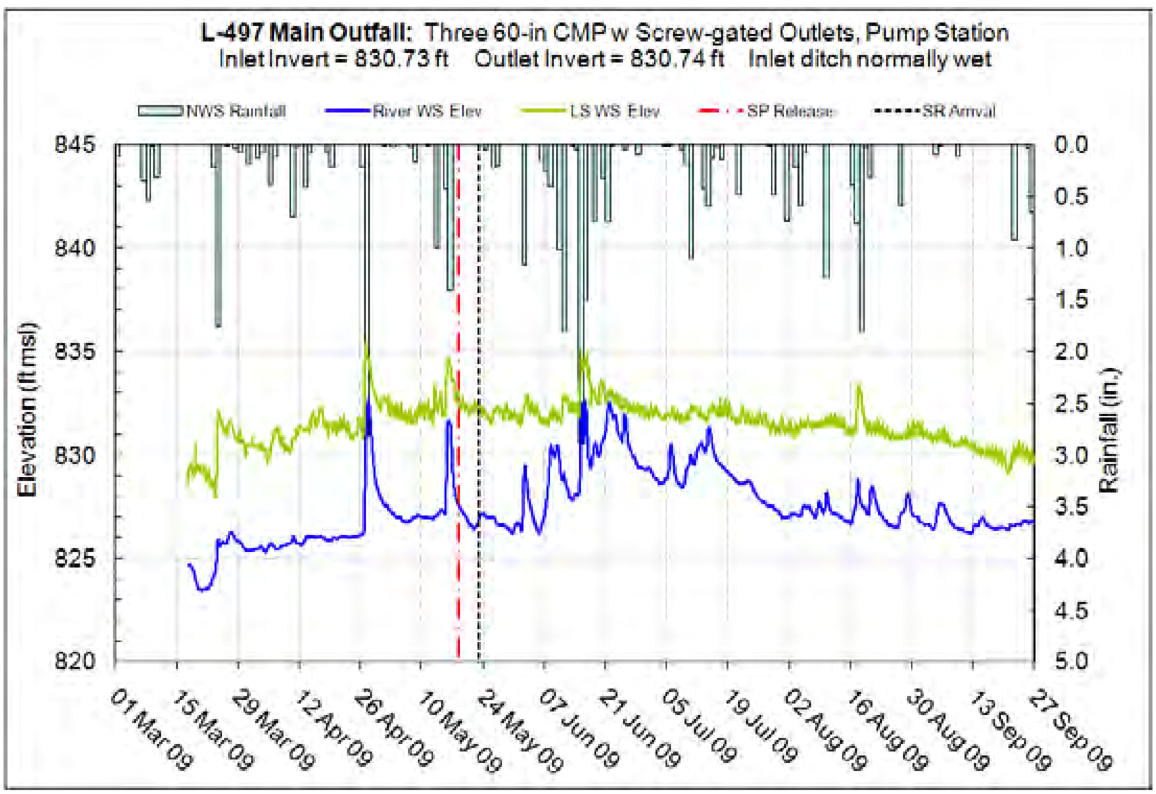

Figure 10.26.5 – Full monitoring record, L-497 Main Outfall

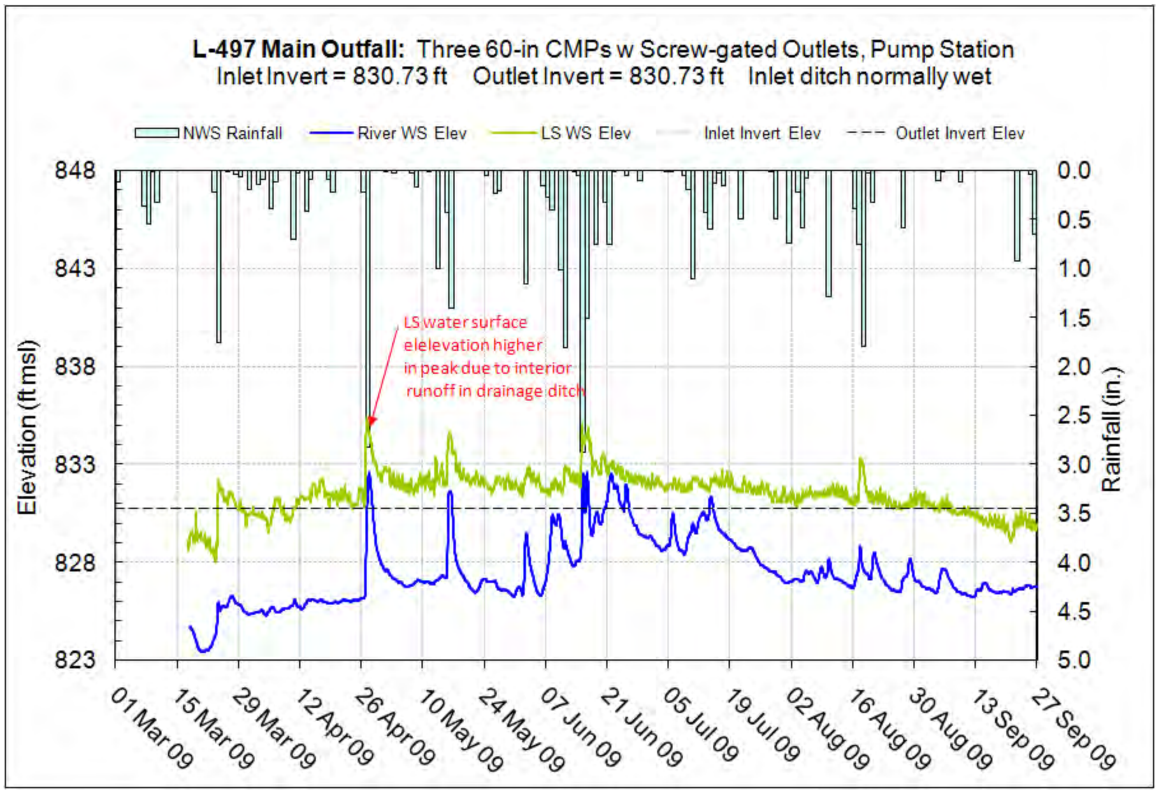

Figure 10.26.6 – Invert elevations, L-497 Main Outfall

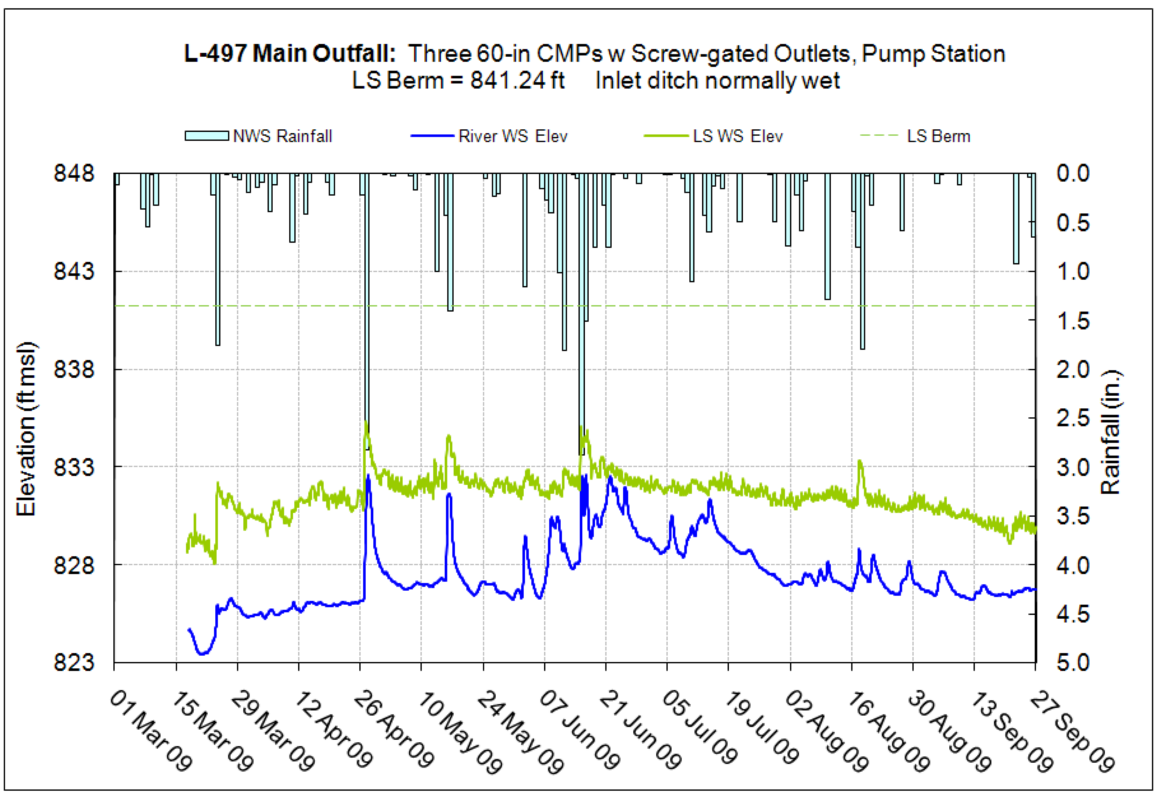

Figure 10.26.7 – Surveyed field elevations, L-497 Main Outfall

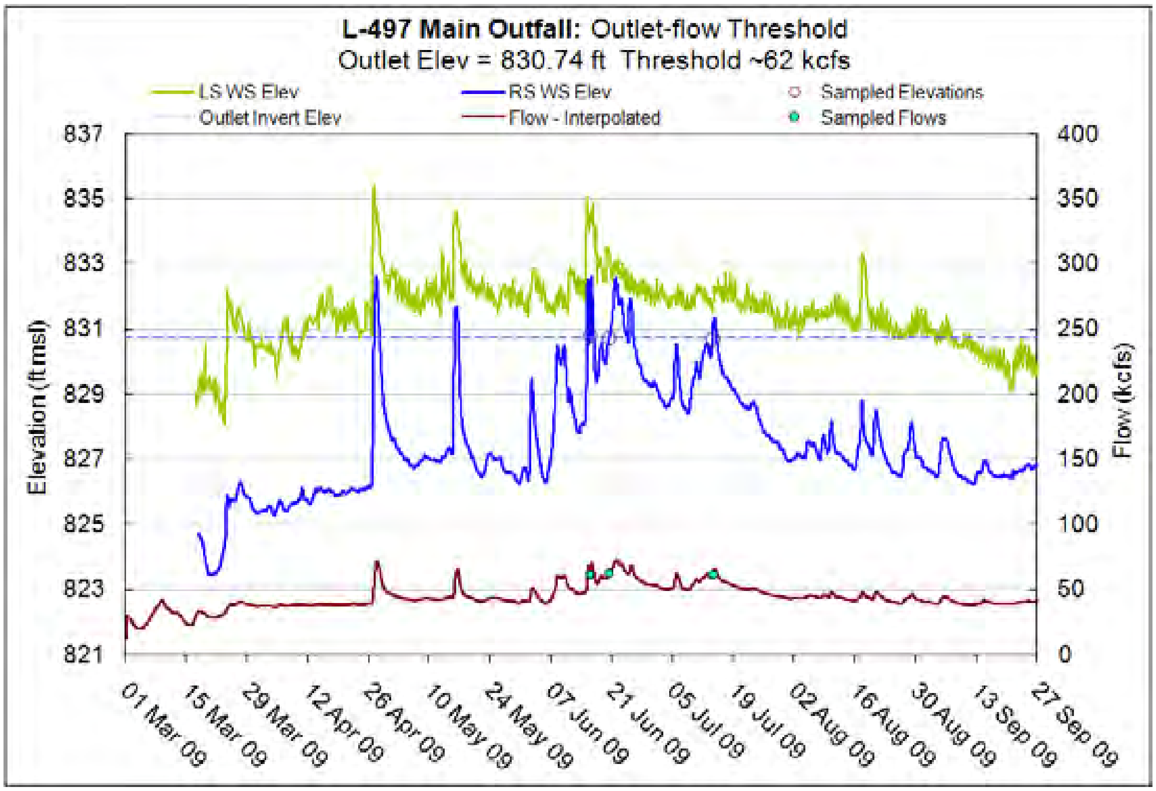

Figure 10.26.8 – Outlet-flow threshold, L-497 Main Outfall

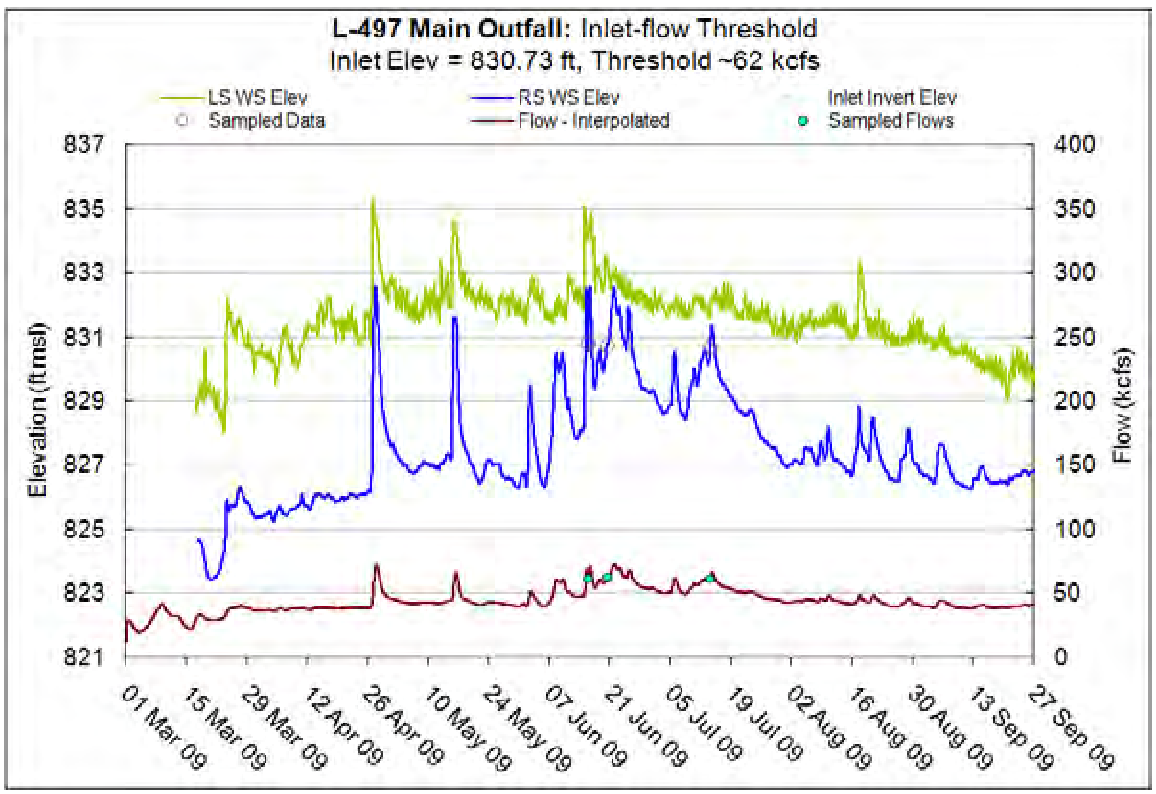

Figure 10.26.9 – Inlet-flow threshold, L-497 Main Outfall

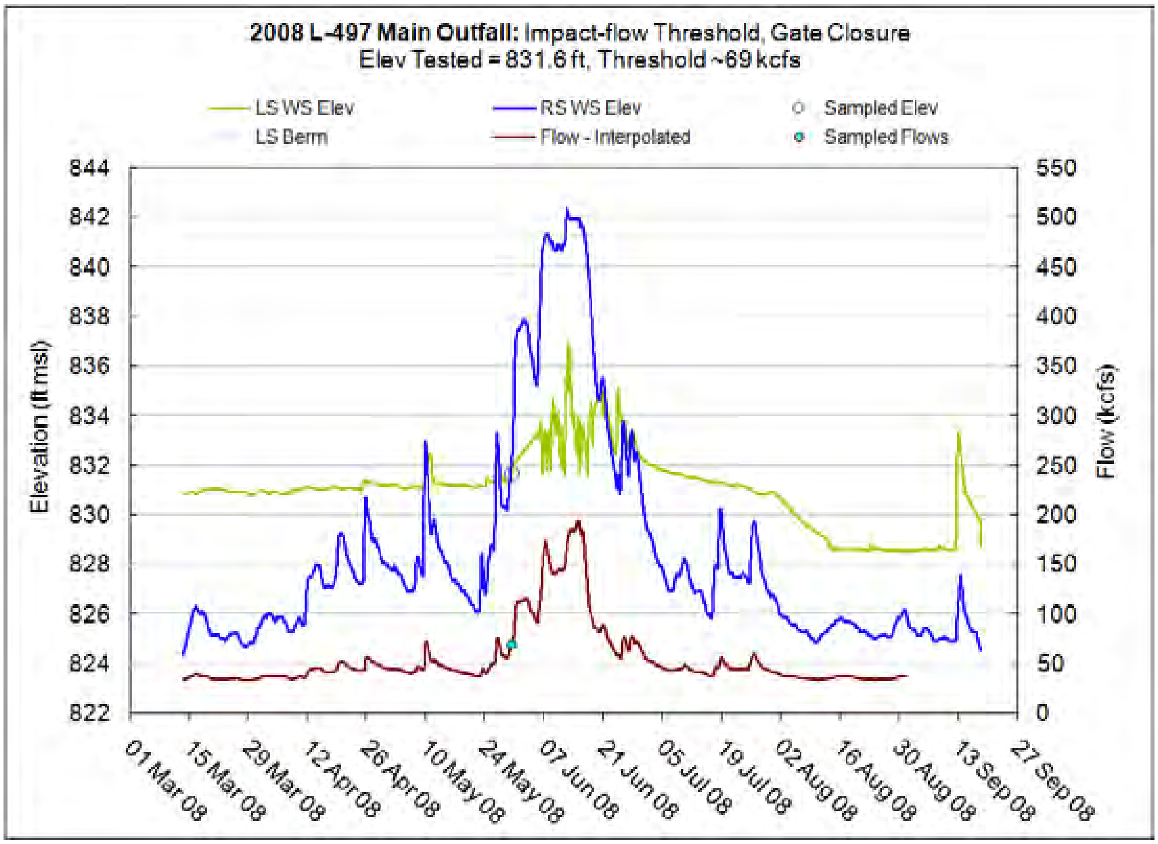

Figure 10.26.10 – Impact-flow threshold (gate closure), L-497 Main Outfall (2008 record)

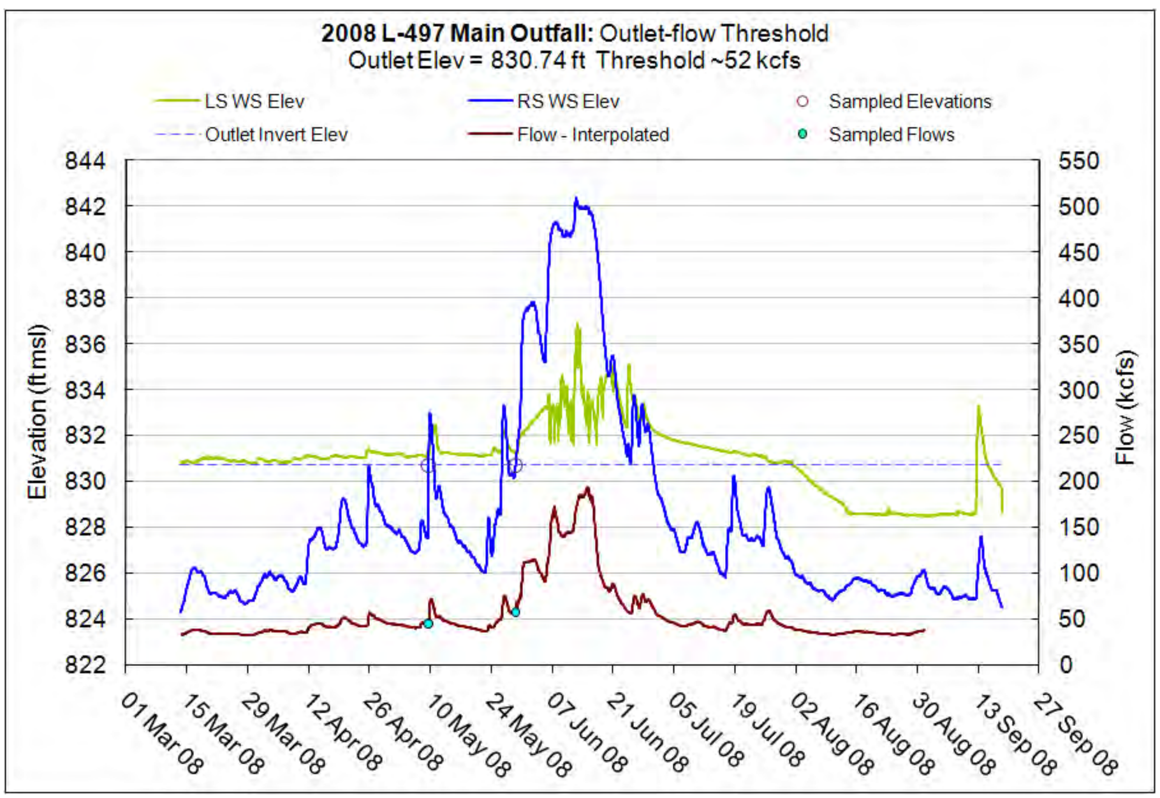

Figure 10.26.11 – Outlet-flow threshold, L-497 Main Outfall

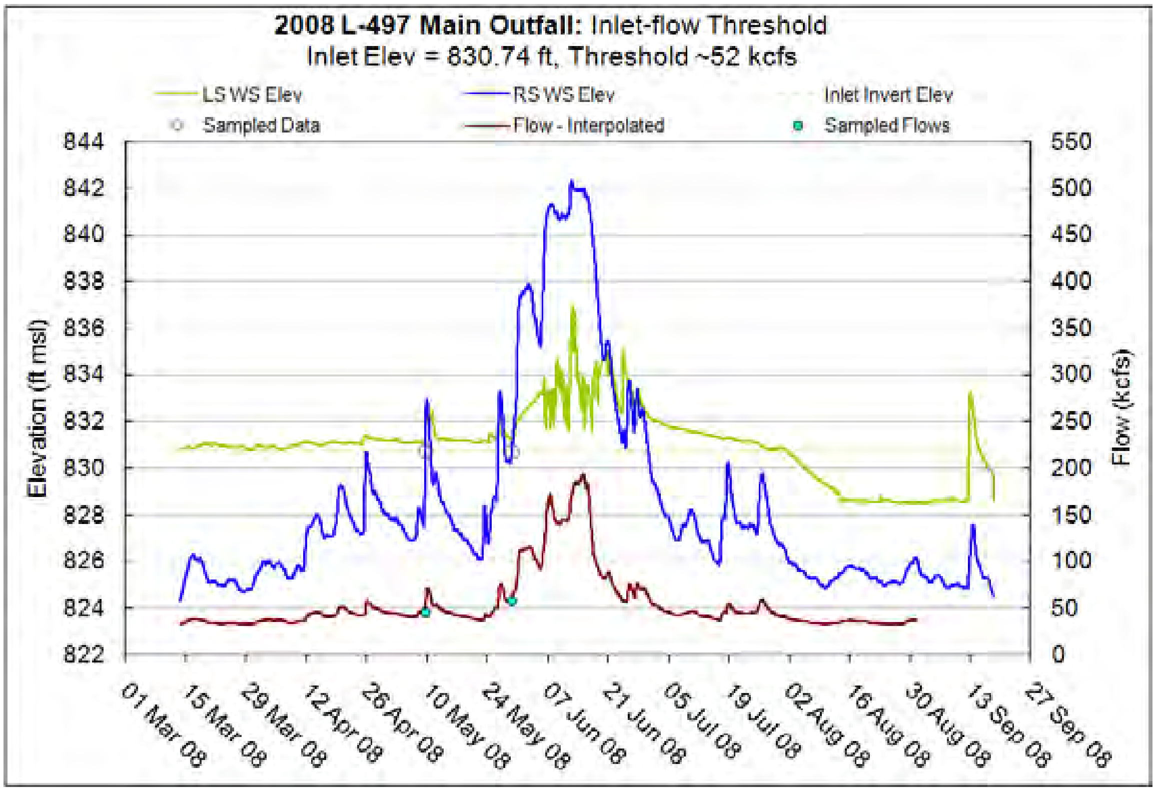

Figure 10.26.12 – Inlet-flow threshold, L-497 Main Outfall (2008 record)

10.27 L-488

The L-488 supplemental gage is located at RM 472.8 on the left bank of the Missouri River between Forbes Bend and Mt. Vernon Bends (Figure 10.27.1). The drainage structure at this site consists of two 72-in. CMPs passing through a concrete headwall of the main levee (Figure 10.27.2). Inlets are not gated, outlets are regulated by slide gates, and there are no berms on either side the inlet ditch. The elevation of the inlet invert of the structure is 825.50 ft, the outlet invert is 824.05 ft, and the top of the levee is 846.45 ft. The left-bank fields are higher than the right-bank fields and the right-bank fields are in an old oxbow. A pump station has its outlet through one of the CMPs (Figure 10.25.2 top left). The LS data logger was installed about 250 ft upstream of the drainage structure inlet. A river data logger was installed on the Missouri River at a private boat ramp at RM 472.5 and its data adjusted up 0.33 ft based on the CRP elevations differences (typical moderate flow profile) between the river gage and the site to obtain the water surface elevations labeled as 'riverside' in the figures.

Field elevations were surveyed in 2009. Two average field elevations were surveyed about 200 ft inland from the culvert inlets on either side of the interior drainage ditch. These elevations are 827.4 ft and 834.7 ft. The lowest elevation (827.4 ft) was used in the analysis. Elevations are in the NAVD 88 datum. Flows were estimated at the site by lagging the flow records of USGS Rulo and USGS St. Joseph to the site based on peaks and then interpolating flows based on river miles.

Water surface elevations collected at this site had a lot of chatter making interpretation of the data difficult. Pumping might have occurred but is not indicated in the graph results as there is too much chatter to know if pumping occurred.

Results and Discussion

§ Table 10.27.1 summarizes the results for the May 2009 created spring rise, and the Missouri River flows estimated to reach the outlet and inlet of the site's drainage structure.

§ Table 10.27.2 summarizes the socioeconomic impacts produced by the natural spring rises at the site in May 2009.

§ Figure 10.27.4 shows the spring pulse release on May 18 and its arrival time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise created by the spring pulse could not be identified due to chatter in the record. Based on the attenuation analysis, the spring pulse accounts for 3.0 kcfs of the total 44-kcfs Missouri River flow at this river mile, or 6.8% of the total flow.

§ Figure 10.27.5 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site shown.

§ Figure 10.27.6 shows the full period of the monitoring record with the inlet- and the outlet-invert elevations of the drainage structure. The grayed-out sections in Figure 10.27.6 are periods of time when either the inlet or outlet (or both) inverts were above the water elevation. These are periods during which socioeconomic impacts from natural spring rises could not have occurred because the RS water-surface elevation was not high enough to reach the invert of the culverts.

§ Figure 10.27.7 shows the 2009 surveyed field elevation for the LS fields.

§ Figure 10.27.8 combines the information gained on the inlet and outlet inverts and the field elevations to separate out possible socioeconomic impacts produced by natural spring rises during the monitoring period. Overbank flooding may have occurred due to

high Missouri River stages and rainfall but was of short duration. Pumping might have also occurred, but there is too much chatter in the record to know for sure.

- Figure 10.27.9 shows the estimation of the overbank-flooding threshold. The estimated threshold flow in the Missouri River for overbank flooding was about 53 kcfs.
- Figure 10.27.10 shows the estimation of the outlet-invert flow threshold. The estimated threshold flow in the Missouri River required to reach the outlet-invert elevation of the site is 51 kcfs.
- Figure 10.27.11 shows the estimation of the inlet-flow threshold. The estimated threshold flow in the Missouri River required to reach the inlet invert elevation of the site is 51 kcfs. This estimate seems low given the flow threshold of the outlet and has a larger degree of error due to the chatter in the record.

Conclusions

No socioeconomic impacts were created by the created spring rise during the 2009 monitoring period at this site. Overbank flooding and pumping may have occurred due to natural spring rises. The total duration of possible overbank flooding varied in duration from 1.8 to 2.7 days. The record was too noisy to conclusively determine if pumping occurred and for what duration. Based on the attenuation analysis, the spring pulse accounts for 3.0 kcfs of the total 44-kcfs Missouri River flow at this river mile, or 6.8% of the total flow.

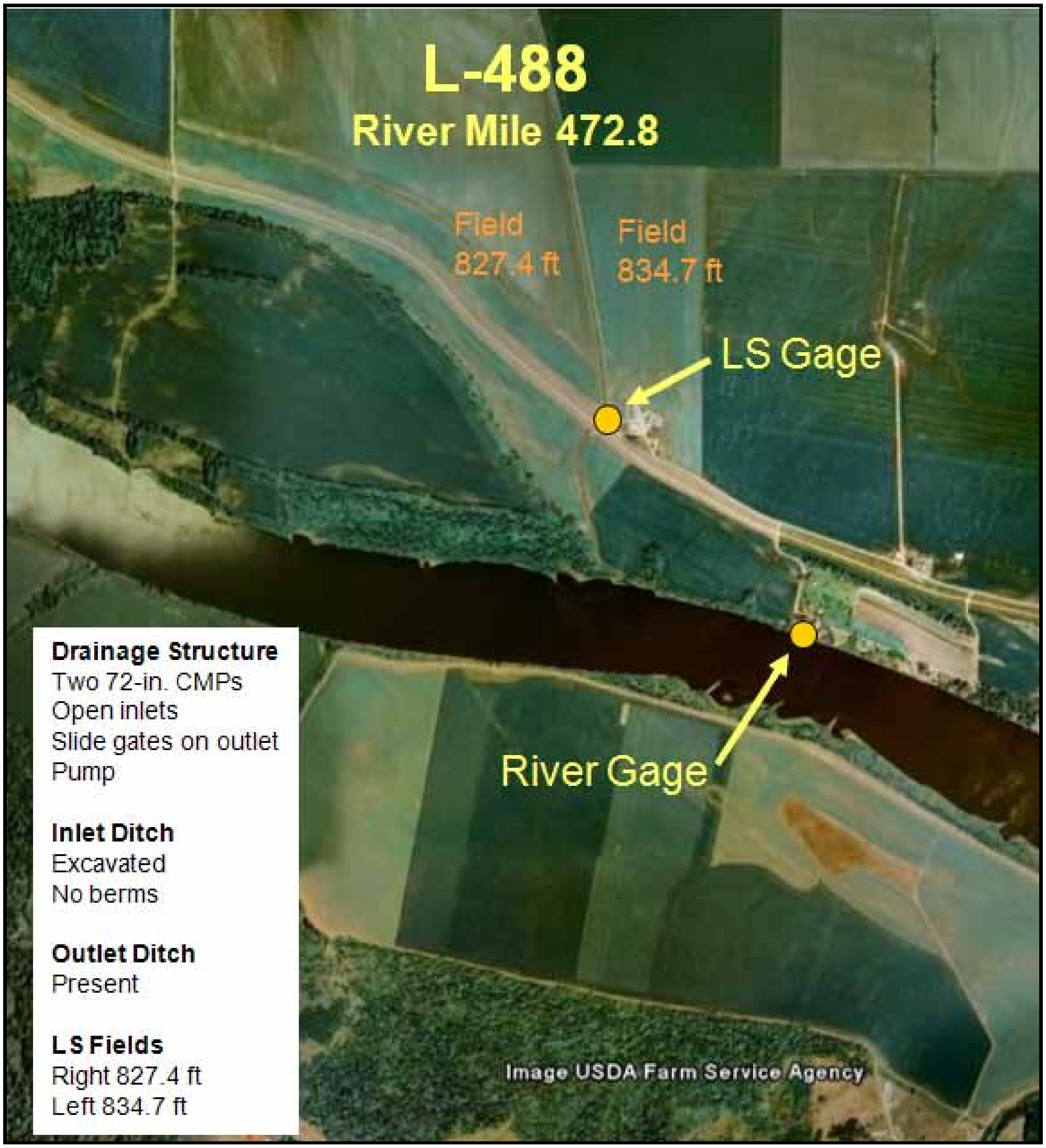

Figure 10.27.1 – L-488 location

Figure 10.27.2 – L-488 site. Landside of levee inlet headwall and pump (top left). Riverside outlet with screw gates (top right). Top of levee looking landward (bottom left). Top of levee looking riverward (bottom right).

Figure 10.27.3 – L-488 gage locations. Landside gage about 250 ft from culvert inlet (left) and river gage (right).

Table 10.27.1 – L-488 results

Spring Pulse from Gavins Point Dam		
	May-09	*Mar-08*
Created spring rise, ft	n.a.[1]	-
Estimated created spring rise flow, kcfs	3.0	-
Estimated MR flow, kcfs	44	-
% of MR flow	6.8	-

Outlet-flow Threshold		
	May-09	*Mar-08*
Elev, ft	824.05	-
Estimated flow at site, kcfs	51	-
Flow at nearest US gage, kcfs	47	-
Nearest US gage	Rulo	-

Inlet-flow threshold		
	May-09	*Mar-08*
Elev, ft	825.50	-
Estimated flow at site, kcfs	51	-
Flow at nearest US gage, kcfs	46	-
Nearest US gage	Rulo	-

[1]Spring rise could not be objectively identified due to chatter in record

Table 10.27.2 – L-488 NSR socioeconomic impacts

2009 Natural Spring Rise Impacts			
	LS Flooding	*Possible Pumping*	*Gate Closure*
Elev, ft	827.4	Can’t determine	Can't determine
Impact duration, dy	1.8 – 2.7	-	-
Estimated flow at site, kcfs	53	-	-
Flow at nearest US gage, kcfs	43	-	-
Nearest US gage	Rulo	Rulo	-

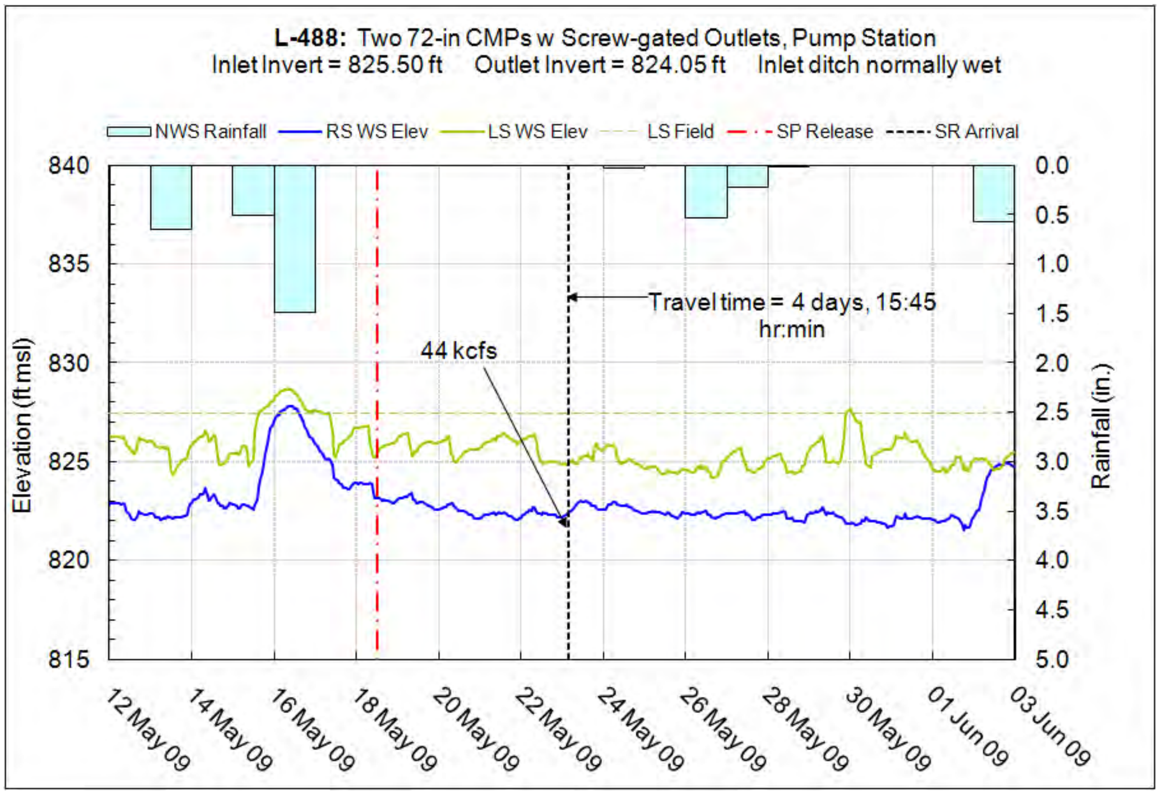

Figure 10.27.4 – Spring rise at L-488

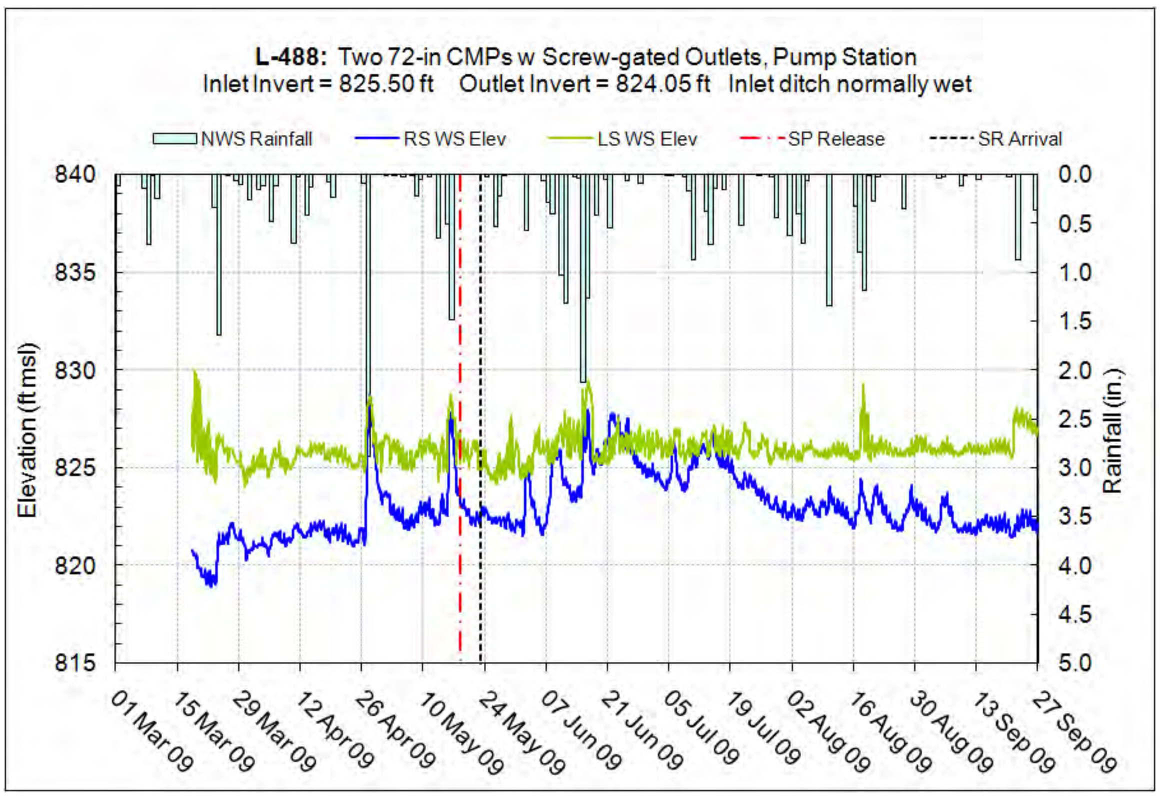

Figure 10.27.5 – Full monitoring record at L-488

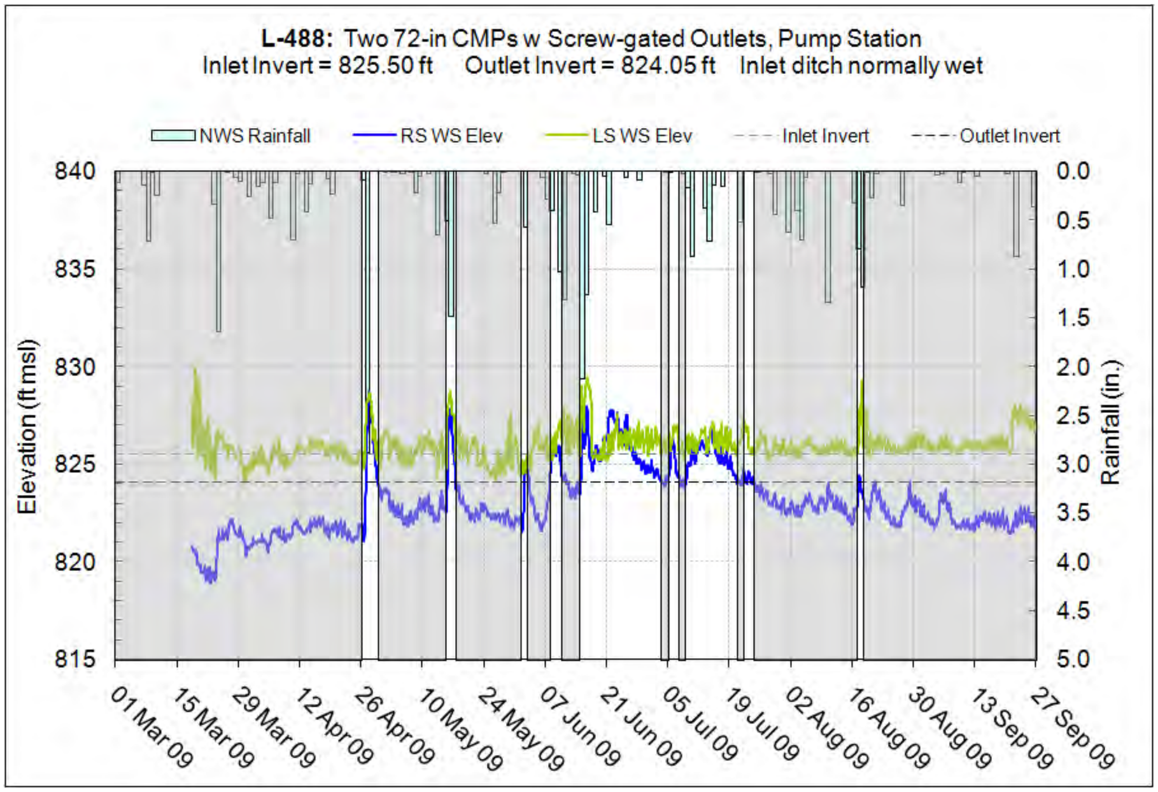

Figure 10.27.6 – Invert elevations, L-488

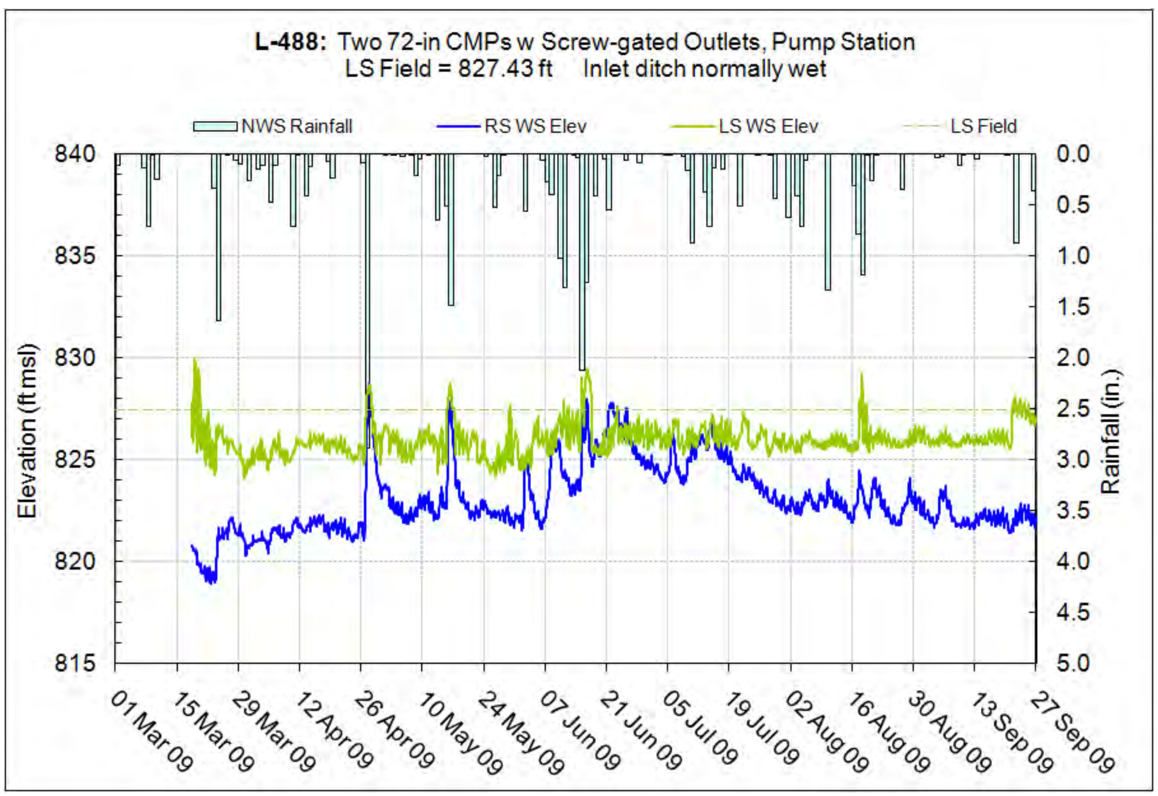

Figure 10.27.7 – Surveyed field elevations, L-488

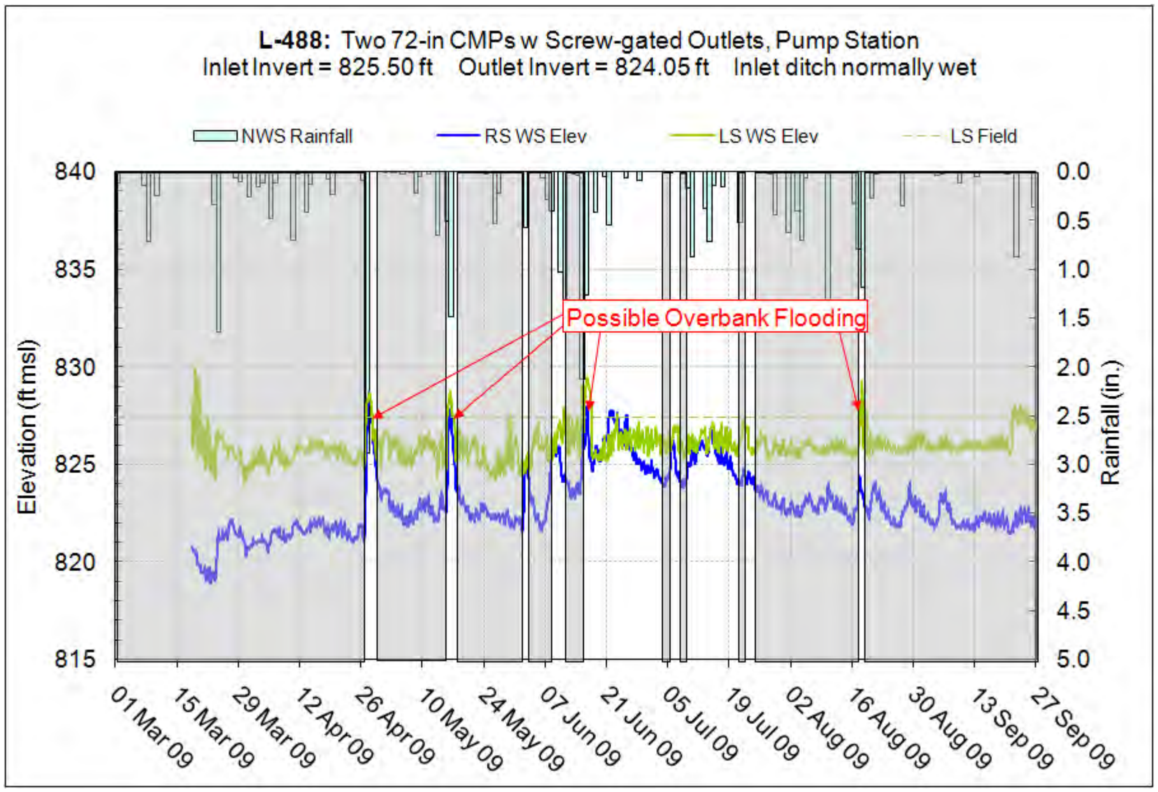

Figure 10.27.8 – NSR socioeconomic impacts, L-488

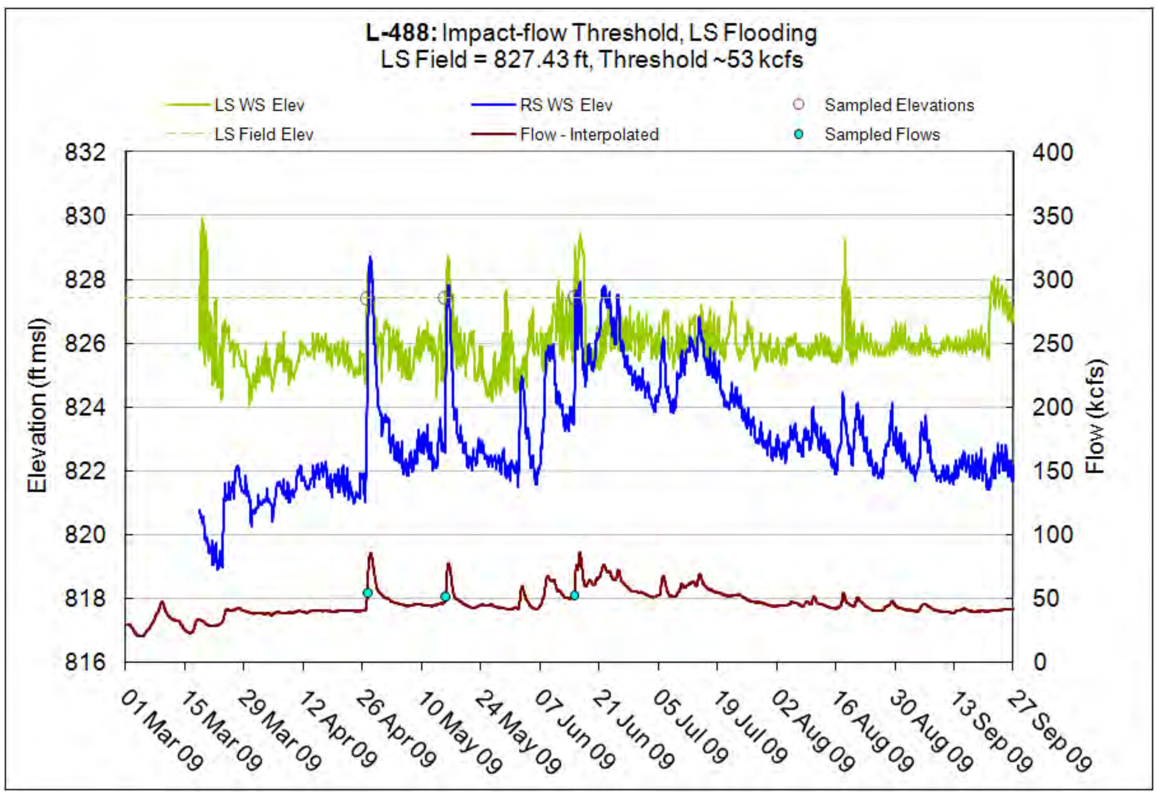

Figure 10.27.9 – Impact-flow threshold (overbank flooding), L-488

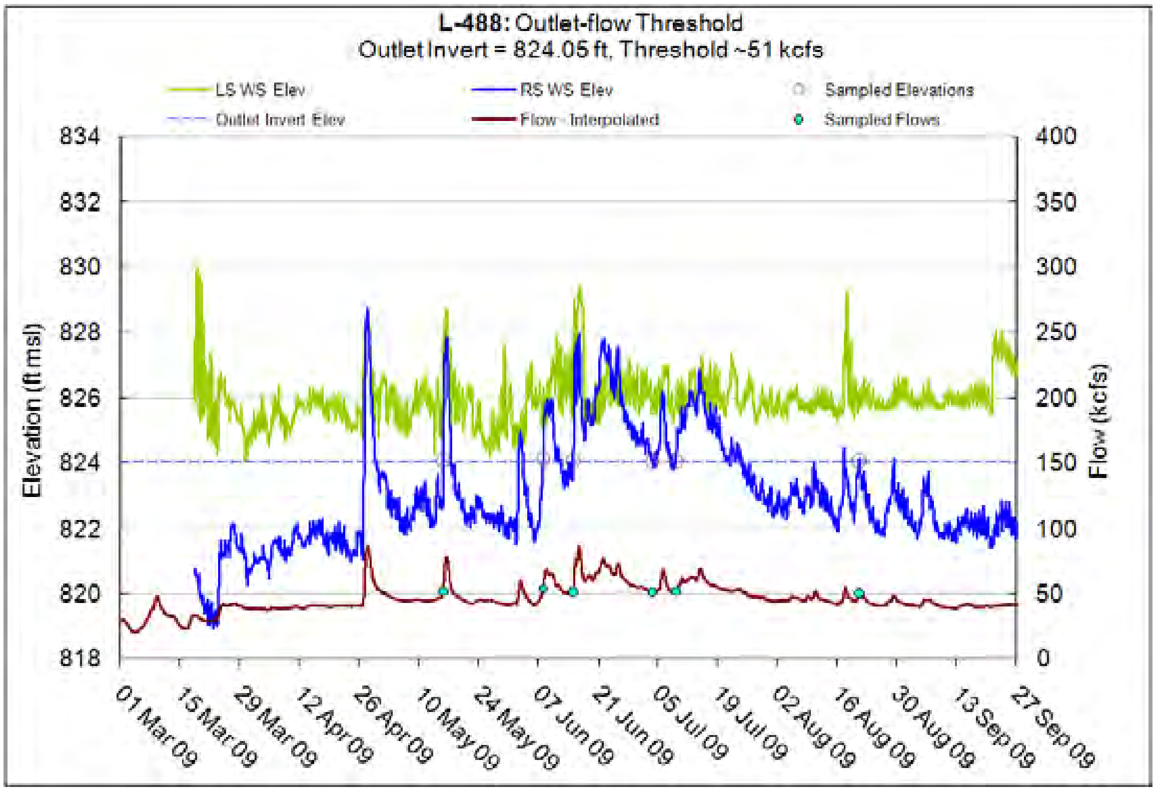

Figure 10.27.10 – Outlet-flow threshold, L-488

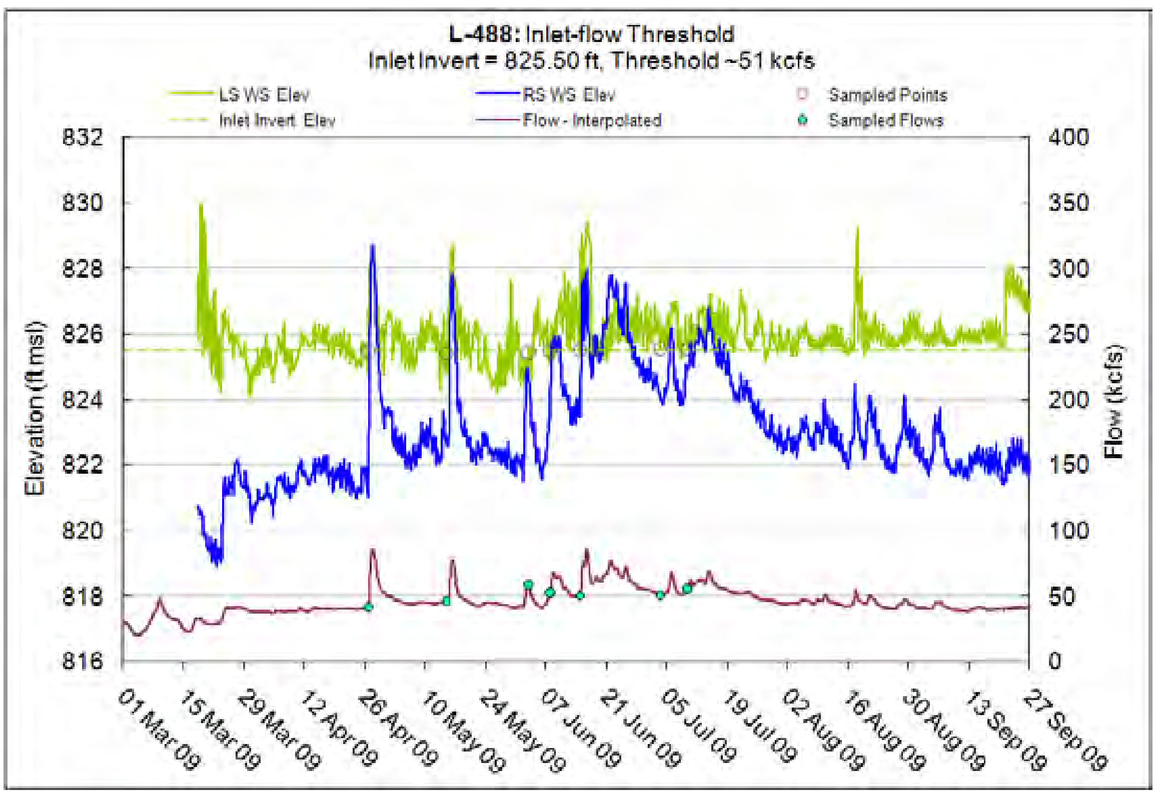

Figure 10.27.11 – Inlet-flow threshold, L-488

10.28 USGS St. Joseph

The USGS Missouri River St. Joseph gage is located at St. Joseph, MO upstream of Highway 36 near the left bank of the Missouri River at river mile 448.2 (Figure 10.28.1). Figure 10.28.2 shows the general travel time of the spring pulse to the site. The created spring rise at this site was approximately 0.5 ft. Figure 10.28.3 shows the full monitoring record with the travel time of the spring pulse noted.

Figure 10.28.1 – USGS St. Joseph location

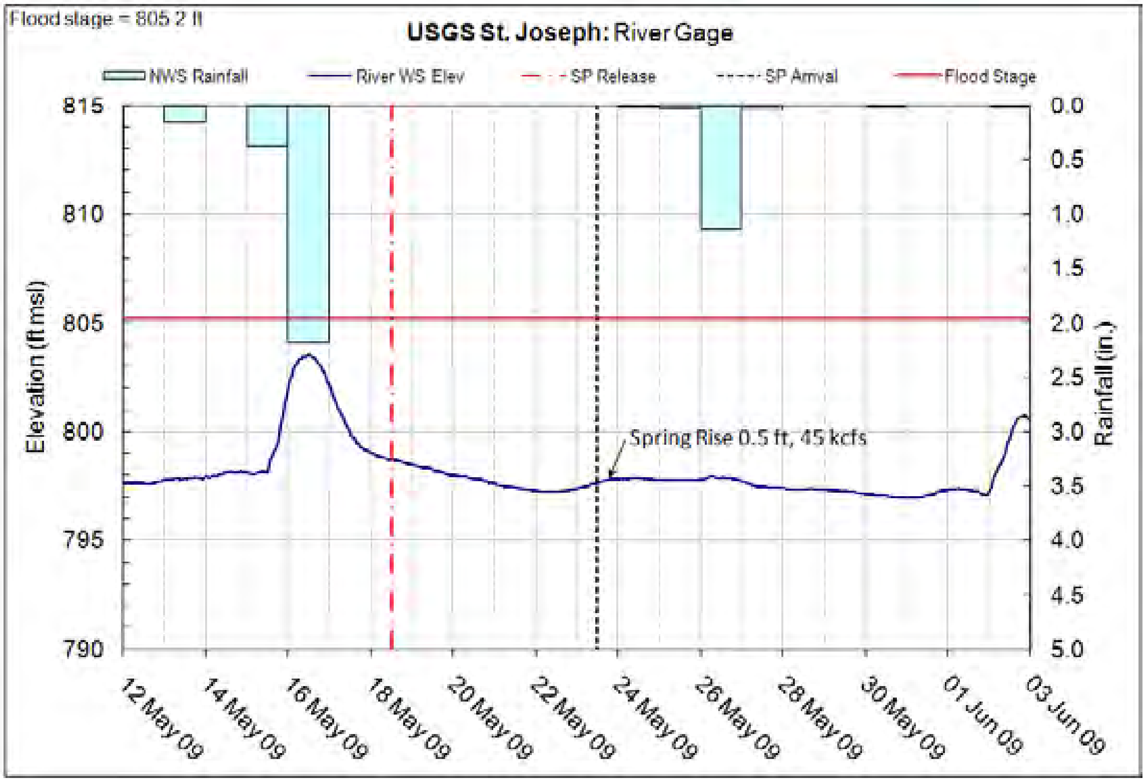

Figure 10.28.2 – Spring rise at St. Joseph

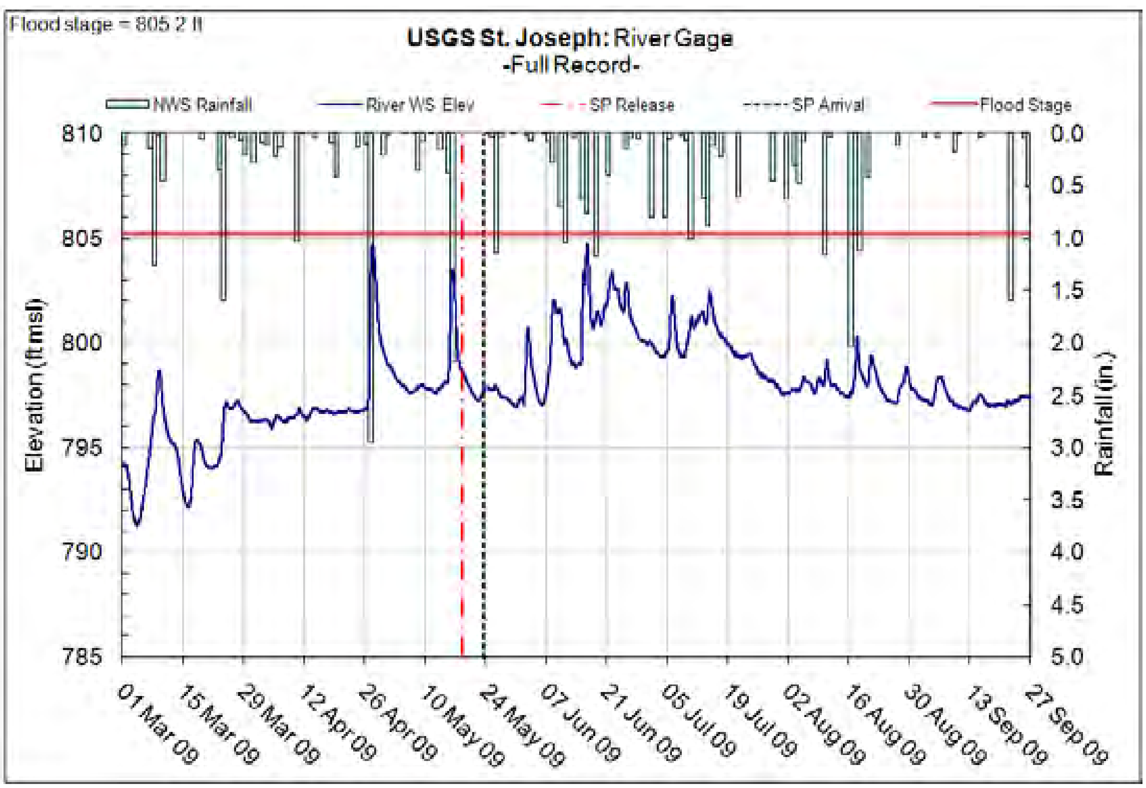

Figure 10.28.3 – Full monitoring record at St. Joseph

10.29 L-448/443

The L-448/443 supplemental gage is located at RM 428.4 on the east side of the Missouri River near Rushville, MO in Buchanan County. The drainage structure at this site consists of four 60-in. CMPs with slide-gated outlets and a pump station. The inlet-invert elevation of the structure is 781.90 ft and the outlet invert elevation is 780.60 ft. Inlets are not gated and the excavated inlet ditch has low berms on each side. The outlet ditch winds downstream to the river. The pump inlet invert appears to be below the inlet invert of the inlet drainage ditches, allowing the drainage ditch to be pumped even when water is below the inverts of the inlets.

Two supplemental gages were installed. The LS gage was installed near the inlet to the drainage structure at RM 428.4. The RS gage was installed 0.2 mi upstream on the Missouri River at RM 428.2 and its collected data adjusted downward 0.19 ft based on the differences in the CRP elevations (typical moderate flow profile) for the two sites to account for elevation differences between the two installed gages.

Field elevations were surveyed in 2009. The surveyed average field elevation about 200 ft inland of the culvert inlets is 788.4 ft. Field elevations upstream and downstream of the inlet ditch were determined to be close to identical. The inlet ditch has low berms with surveyed elevations of 793.3 and 793.5 ft. The lowest berm elevation (793.3 ft) was used in the analysis. Elevations are in the NAVD 88 datum. Flows were estimated at the site by lagging the flow records of USGS St. Joseph and USGS Kansas City to the site based on peaks and then interpolating flows based on river miles.

Results and Discussion

- Table 10.29.1 summarizes the results for the May 2009 created spring rise, and the Missouri River flows estimated to reach the outlet and inlet of the site's drainage structure. This site was not monitored in 2008.
- Figure 10.29.4 shows the spring pulse release on May 18 and its arrival time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise created by the May spring pulse was 0.5 ft. Based on the attenuation analysis, the spring pulse accounts for 2.4 kcfs of the total 48-kcfs Missouri-River flow at this river mile, or 5.0% of the total flow.
- Figure 10.29.5 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site shown.
- Figure 10.29.6 shows the March through August 2009 portion of the monitoring record with the inlet- and outlet-invert elevations of the drainage structure. The grayed-out sections in Figure 10.29.6 are periods of time when either the inlet or the outlet (or both) inverts were above the water elevation. These are periods during which socioeconomic impacts from natural spring rises could not have occurred because the RS water elevation was not high enough to reach the invert of the culverts.
- Figure 10.29.7 shows the 2009 surveyed field elevation for the LS berm. Figure 10.29.7 shows pumping may have occurred two times in the record in mid-May and August. However, this pumping largely occurred when the water level was below the invert elevations of the inlet and outlets. Because pumping occurred for reasons other than to respond to possible high water levels, these periods of possible pumping were not documented in Table 1 as socioeconomic impacts.
- Figure 10.29.8 shows the estimation of the outlet-invert flow threshold. The estimated threshold flow in the Missouri River required to reach the outlet-invert elevation of the

site is about 51 kcfs at the river mile of the site or 46 kcfs at the St. Joseph gage upstream.

§ Figure 10.29.9 shows the estimation of the inlet-invert flow threshold. The estimated threshold flow in the Missouri River required to reach the inlet-invert elevation of the site is about 57 kcfs at the site or 51 kcfs at the St. Joseph gage upstream.

Conclusions

No socioeconomic impacts due to the created spring rise were observed. Based on the attenuation analysis, the spring pulse accounts for 2.4 kcfs of the total 48-kcfs Missouri-River flow at this river mile, or 5.0% of the total flow. Minor overbank flooding (less than 1 ft deep) was the impact identified from natural spring rises. Overbank flooding occurred once in the record on the LS of the levee and the duration of the flooding was 0.8 days.

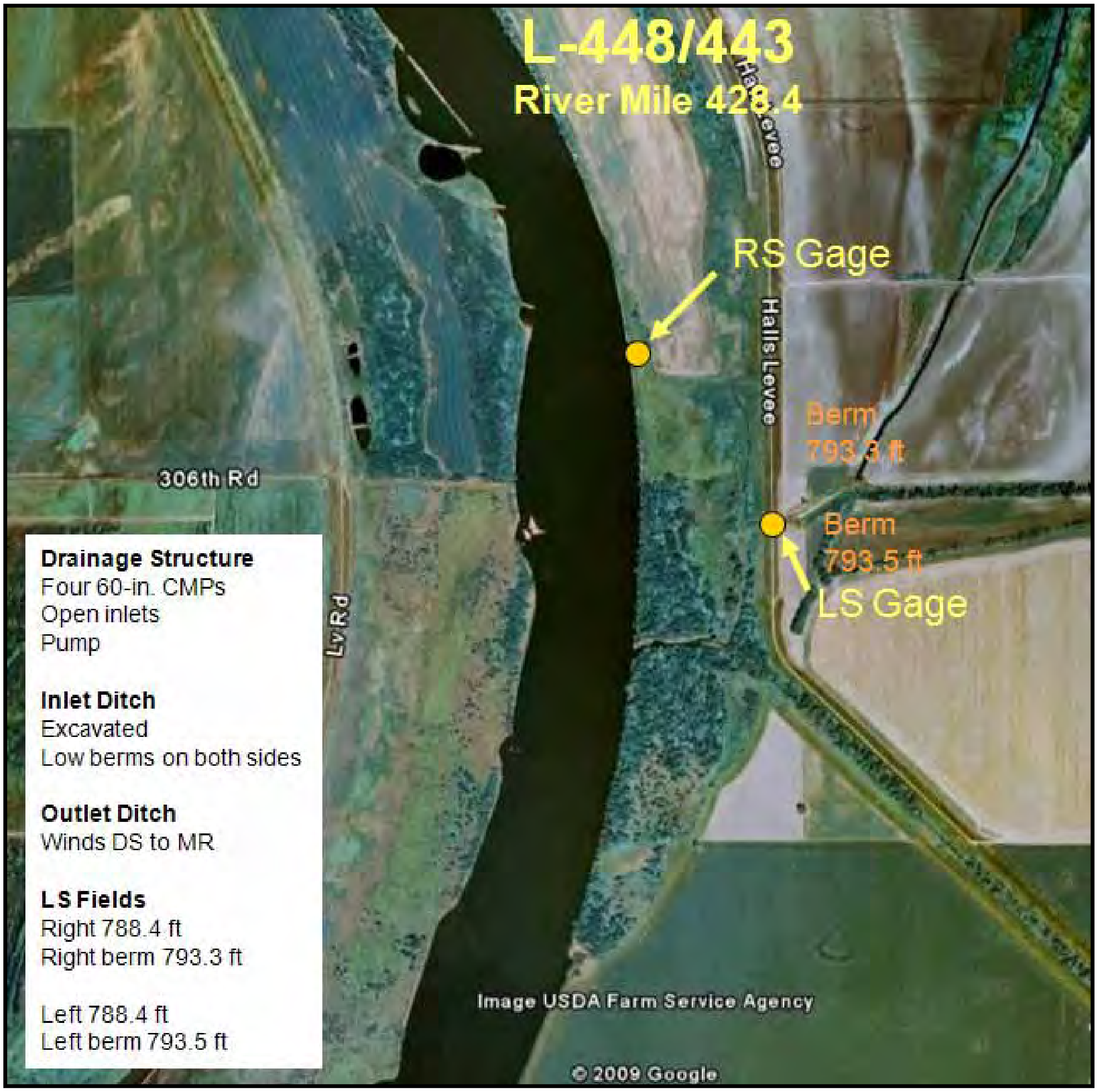

Figure 10.29.1 – L-448/443 location

Figure 10.29.2 – L-448/433 site. Four 60-in CMP inlets and pump station (top left). Concrete outlet gate structure with screw-gates (top right). Top of levee looking landward at fields (bottom left). Top of levee looking riverward (bottom right).

Figure 10.29.3 – L-448/433 gages. Landside data logger (left). River data logger on river bank (right).

Table 10.29.1 – L-448/443 results

Spring Pulse from Gavins Point Dam	*May-09*	*Mar-08*
Created spring rise, ft	0.5	-
Estimated created spring rise flow, kcfs	2.4	-
Estimated MR flow, kcfs	48	-
% of MR flow	5	-

Outlet-Flow Threshold	*May-09*	*Mar-08*
Elev, ft	780.60	-
Estimated flow at site, kcfs	51	-
Flow at nearest US gage, kcfs	46	-
Nearest US gage	St. Joseph	-

Inlet-Flow Threshold	*May-09*	*Mar-08*
Elev, ft	781.90	-
Estimated flow at site, kcfs	57	-
Flow at nearest US gage, kcfs	51	-
Nearest US gage	St. Joseph	-

Impacts

No observed socioeconomic impacts.

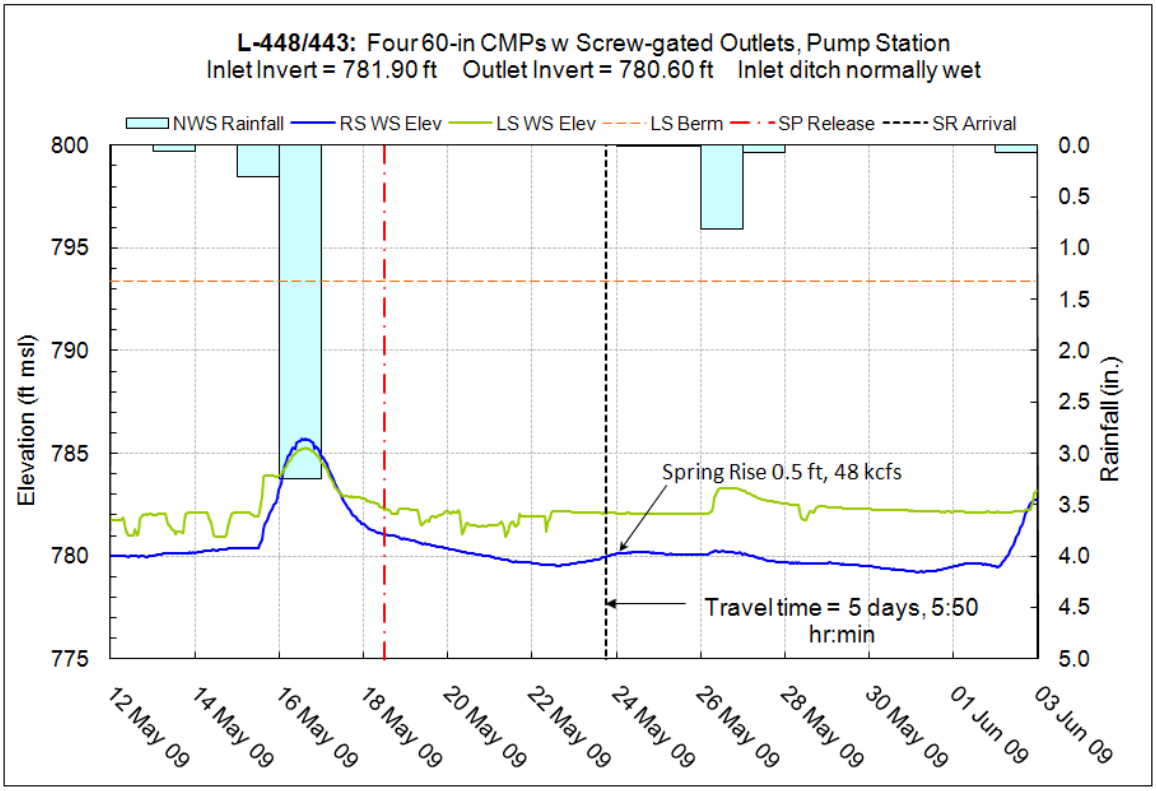

Figure 10.29.4 – Spring rise at L-448/443

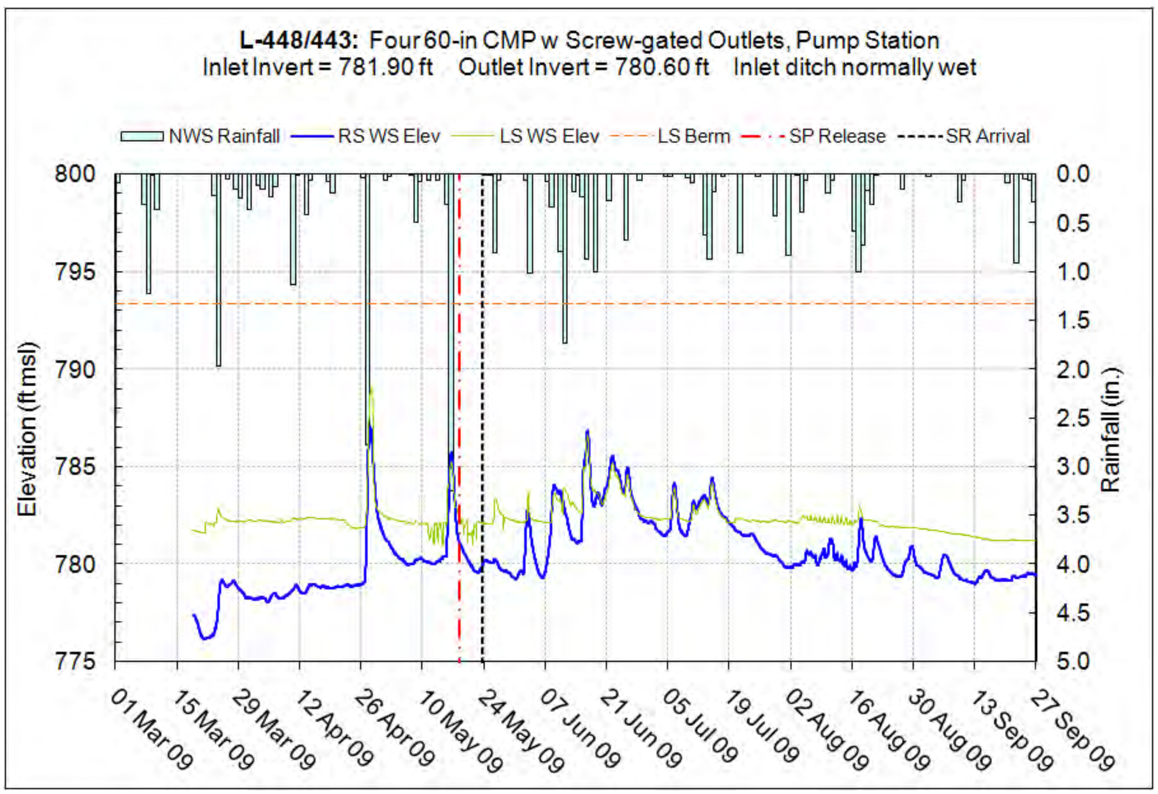

Figure 10.29.5 – Full monitoring record, L-448/443

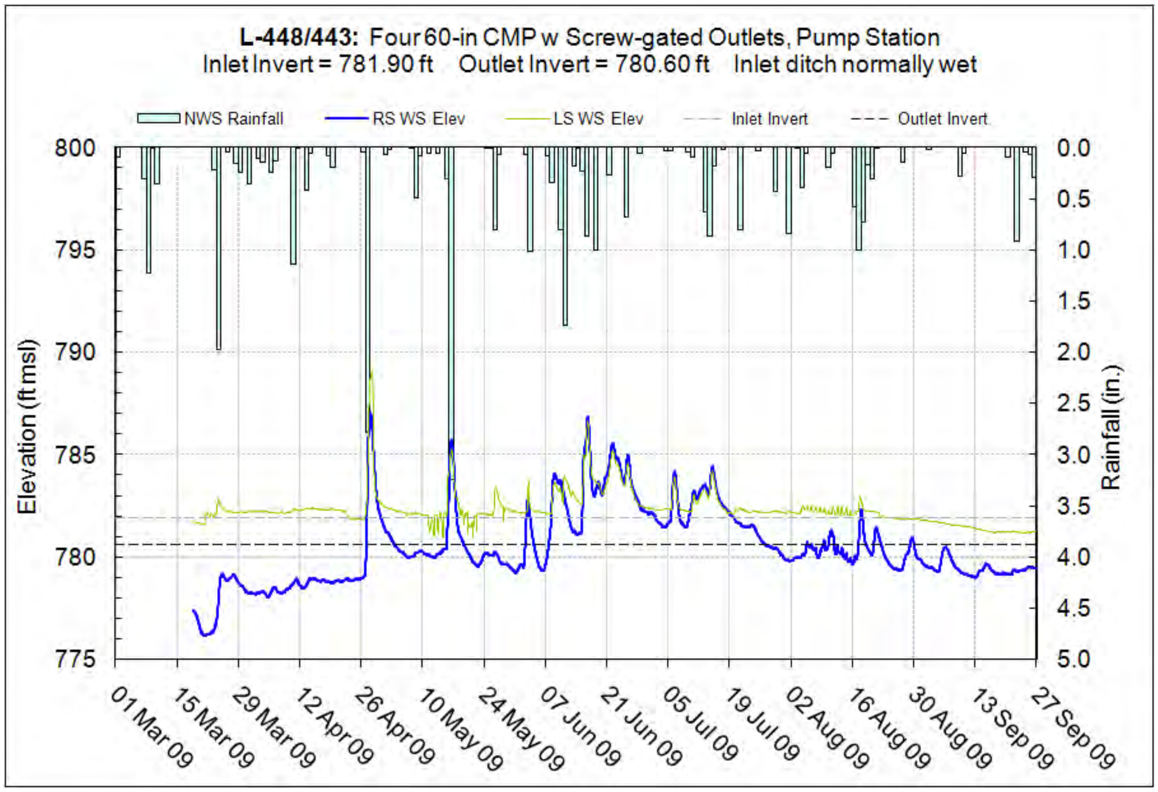

Figure 10.29.6 – Invert elevations, L-448/443

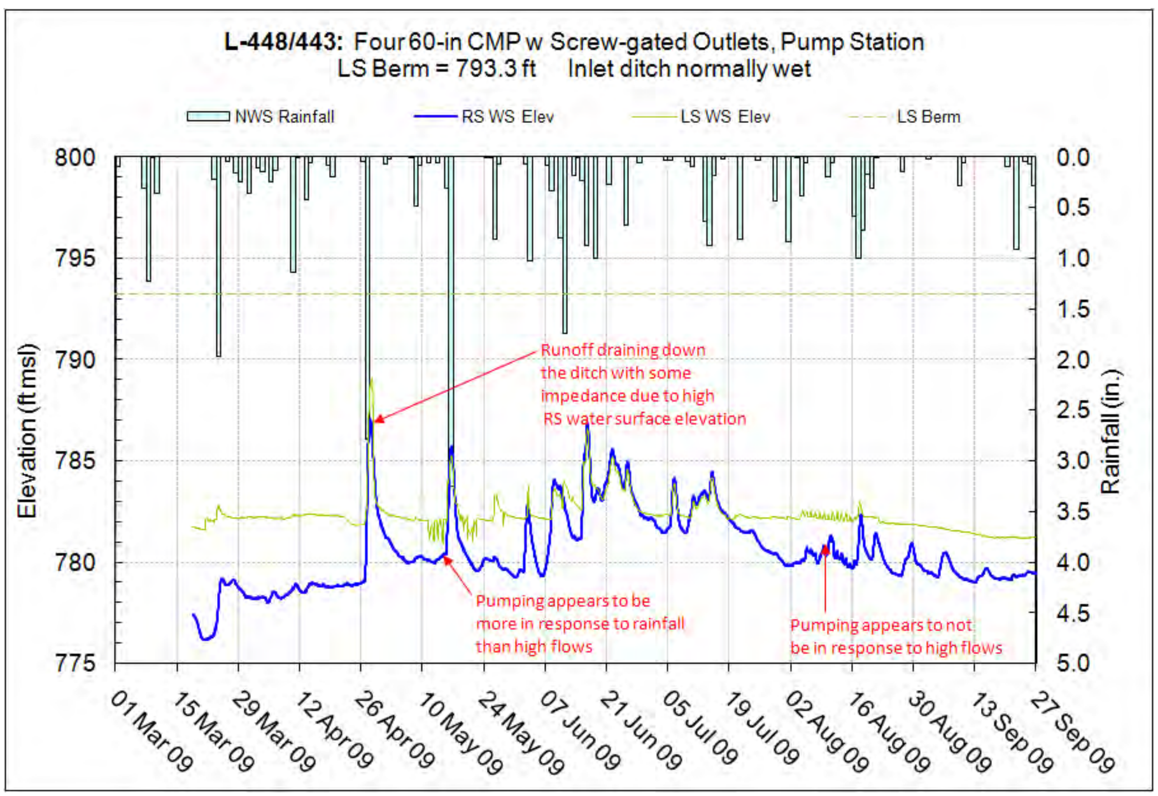

Figure 10.29.7 – Surveyed field elevations, L-448/443

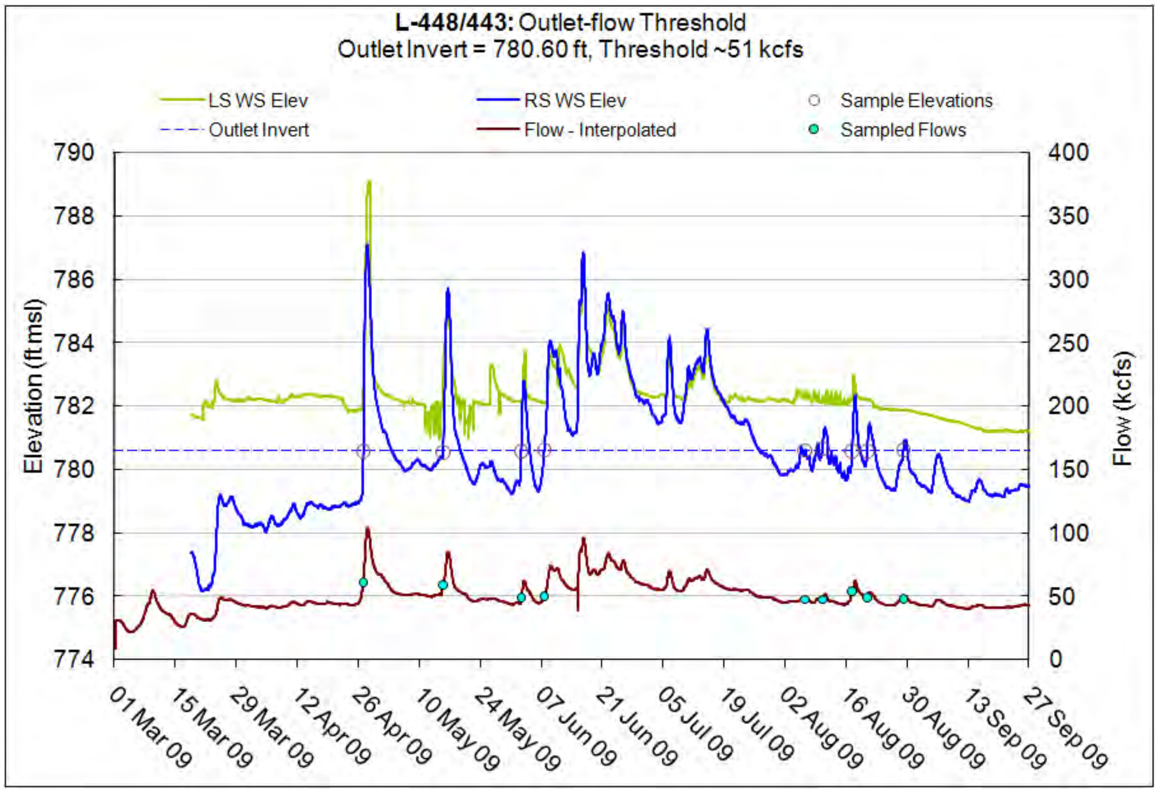

Figure 10.29.8 – Outlet-flow threshold, L-448/443

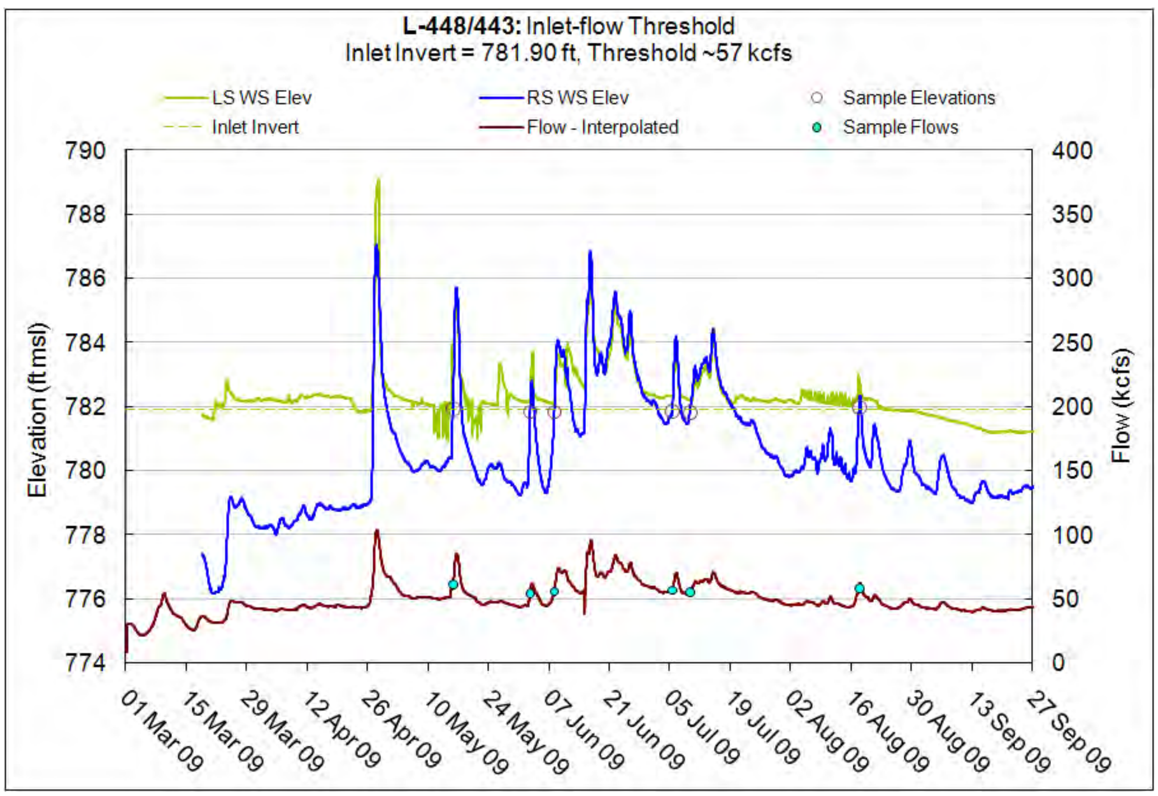

Figure 10.29.9 – Inlet-flow threshold, L-448/443

10.30 L-408 Main Outfall (DCP)

The L-408 Main Outfall supplemental gage was installed as a temporary DCP in April 2008. This site is located northeast of Lansing, KS on the left bank of the Missouri River at river mile 391.9 (Figure 10.30.1) in the Delaware Bend. The drainage structure at this site is a single 6' x 5' box culvert (Figure 10.30.2) with a slide gate in the gatewell at the centerline of the levee and a flap gate at the outlet. The site does not have a pump station.

The DCP installed at this site collects data at both the RS and LS of the levee (Figure 10.30.3). The RS orifice line is located near on the river bank near the outlet ditch and the LS orifice line is located in the ponding area upstream of the culvert. The culvert's inlet elevation is 747.28 ft (msl), its outlet elevation is 745.94 ft (msl), and the elevation of the levee above the culvert is 773.90 ft (msl). Note that these elevations are different than the elevations reported in the 2008 report because the new elevations were taken in the NAVD 88 datum and not the NGVD 29 datum. A drainage ditch about 420 ft in length connects the culvert outlet with the Missouri River.

Field elevations were surveyed in 2009. The fields on both sides of the inlet ditch are 753 ft in the brush just outside of the berms, then rises to about 758 to 762 in the fields away from the berms. The average LS field elevation used in the figures is 759 ft. Fields on the RS of the levee are about 760 ft. All elevations are in the NAVD 88 datum. Flows were estimated at the site by lagging the flow records of USGS St. Joseph and USGS Kansas City to the site based on peaks and then interpolating flows based on river miles.

Results

§ Table 10.30.1 summarizes the results for the May 2009 and March 2008 created spring rises, and the Missouri River flows estimated to reach the outlet and inlet of the site's drainage structure.

§ Table 10.20.2 summarizes the socioeconomic impacts produced by the natural spring rises at the site in May 2009 and March 2008.

§ Figure 10.30.4 shows the spring pulse release on May 18 and its arrival time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise created by the May spring pulse was 0.3 ft. Based on the attenuation analysis, the spring pulse accounts for 1.9 kcfs of the total 53-kcfs Missouri River flow at this river mile, or 3.6% of the total flow.

§ Figure 10.30.5 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site.

§ Figure 10.30.6 shows the full period of the monitoring record with the inlet and outlet invert elevation of the drainage structure.

§ Figure 10.30.7 shows the 2009 surveyed field elevations for the RS and LS fields. No socioeconomic impacts were observed at this site.

§ Figure 10.30.8 shows the estimate of the outlet-flow threshold. The Missouri River has to be over 66 kcfs to reach the outlet invert.

§ Figure 10.30.9 shows the estimation of the inlet-flow threshold. The estimation of this threshold was not as straightforward at the estimation of the outlet-threshold because the LS ditch is usually wet. In the case of this site, the water surface elevation does not drop below the inlet invert elevation for the length of the monitoring record. In this case, the inlet invert elevation was graphed, and the RS water elevation was used to estimate

the threshold. The estimated inlet-flow threshold was 75 kcfs at the site river mile or 51 kcfs at the USGS St. Joseph gage upstream of the site.

§ Figure 10.30.10 shows the impact-flow threshold estimate for gate closures in 2008. Gates appear to have closed when flows at the site reached around 94 kcfs.

§ Figure 10.30.11 shows the estimate of the outlet-flow threshold with 2008 data. Flows in the Missouri River were estimated to be around 71 kcfs to reach the outlet invert of the drainage structure.

§ Figure 10.30.12 shows the estimate of the inlet-flow threshold with 2008 data. Flows in the Missouri River were estimated to be around 76 kcfs to reach the inlet invert of the drainage structure.

Conclusions

No socioeconomic impacts were created by either the created or natural spring rises during the 2009 monitoring period at this site. Based on the attenuation analysis, the spring pulse accounts for 1.9 kcfs of the total 53 kcfs Missouri River flow at this river mile, or 3.6% of the total flow.

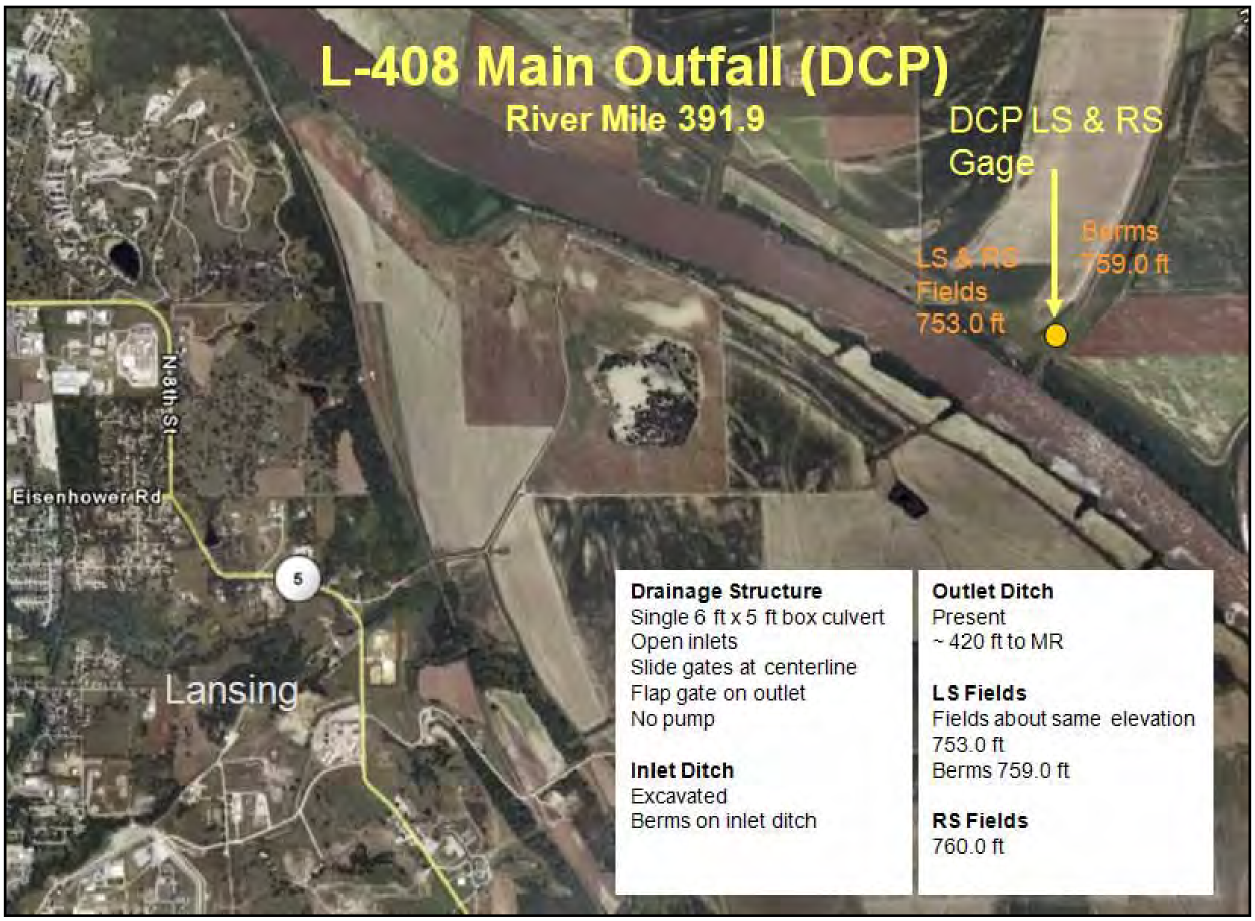

Figure 10.30.1 – L-408 location

Figure 10.30.2 – L-408 site. Sensor pipe on 6-ft x 5-ft RCB culvert inlet headwall (top left). Outlet drainage ditch looking toward levee before DCP installation (top right). Top of levee looking landward (bottom left). Top of levee looking riverward before DCP installation (bottom right).

Figure 10.30.3 – L-408 DCP gage. DCP monitors both LS and RS water surface elevations.

Table 10.30.1 – L-408 results

Spring Pulse from Gavins Point Dam	***May-09***	***Mar-08***
Created spring rise, ft	0.3	n.a.
Estimated created spring rise flow, kcfs	2.0	n.a.
Interpolated MR flow, kcfs	53	n.a.
% of MR flow	3.7	n.a.

Outlet--Flow Threshold	***May-09***	***Mar-08***
Elev, ft	745.94	745.94
Interpolated flow, kcfs	66	71
Flow at nearest US gage, kcfs	51	53
Nearest US gage	St. Joseph	St. Joseph

Inlet-Flow Threshold	***May-09***	***Mar-08***
Elev, ft	747.28	747.28
Interpolated flow, kcfs	75	76
Flow at nearest US gage, kcfs	51	59
Nearest US gage	St. Joseph	St. Joseph

n.a. not applicable, monitoring not in place at time of spring rise

Table 10.30.2 – L-408 NSR socioeconomic impacts

2009 Natural Spring Rise Impacts

No observed socioeconomic impacts.

2008 Natural Spring Rise Impacts

	Gate Closure	*LS Flooding*
Elev, ft	-	759.0
Total impact duration, dy	19	No flooding
Interpolated flow, kcfs	94	-
Flow at nearest US gage, kcfs	73	-
Nearest US gage	St. Joseph	-

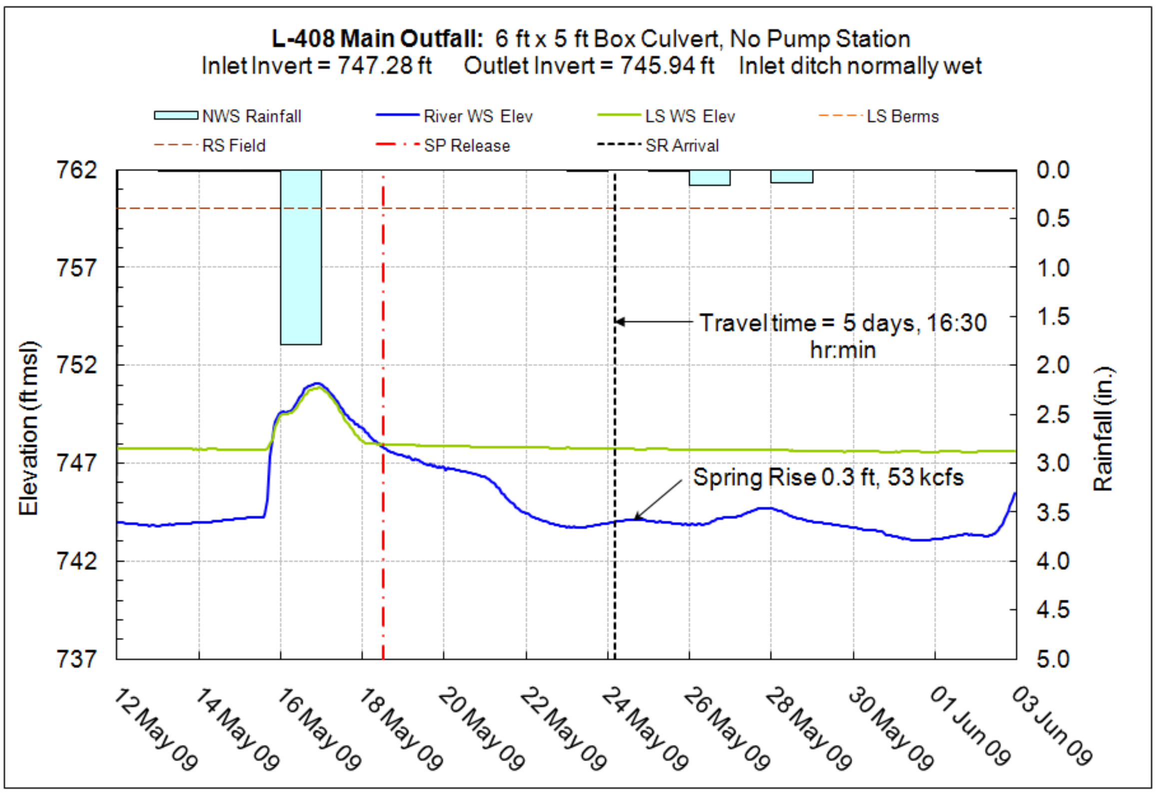

Figure 10.30.4 – Spring rise at L-408

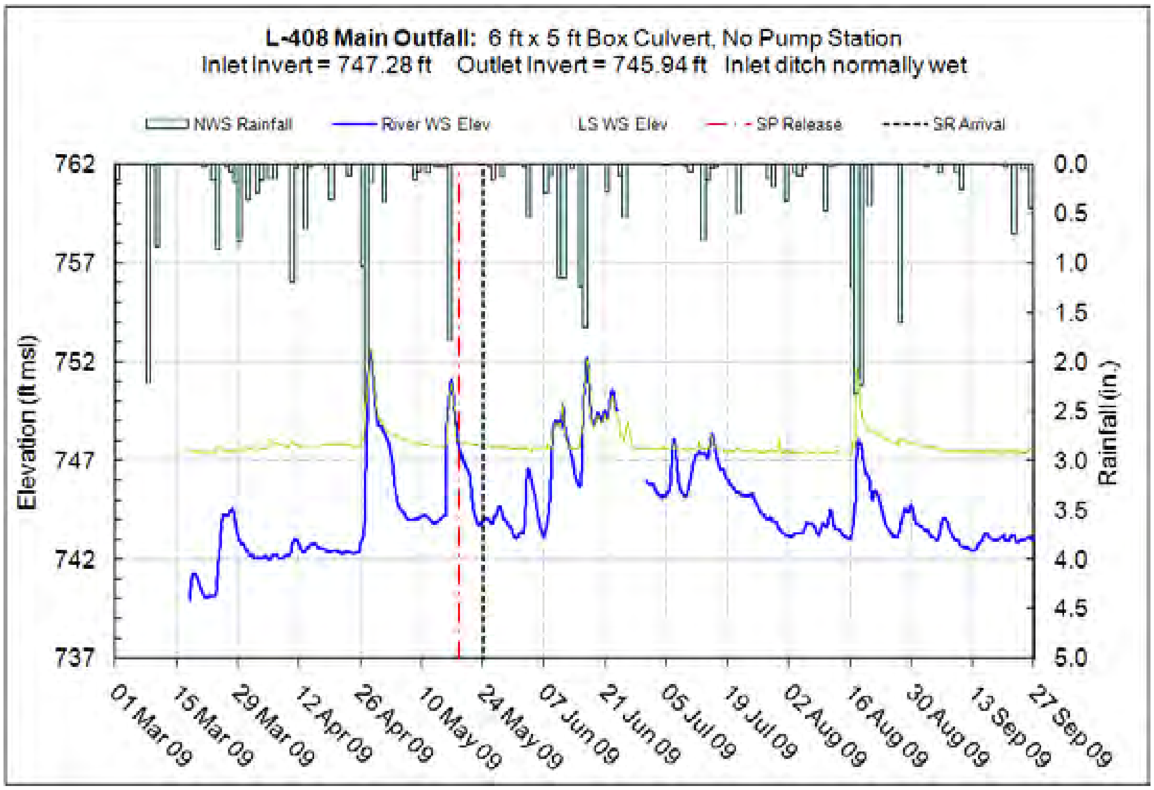

Figure 10.30.5 – Full monitoring record at L-408

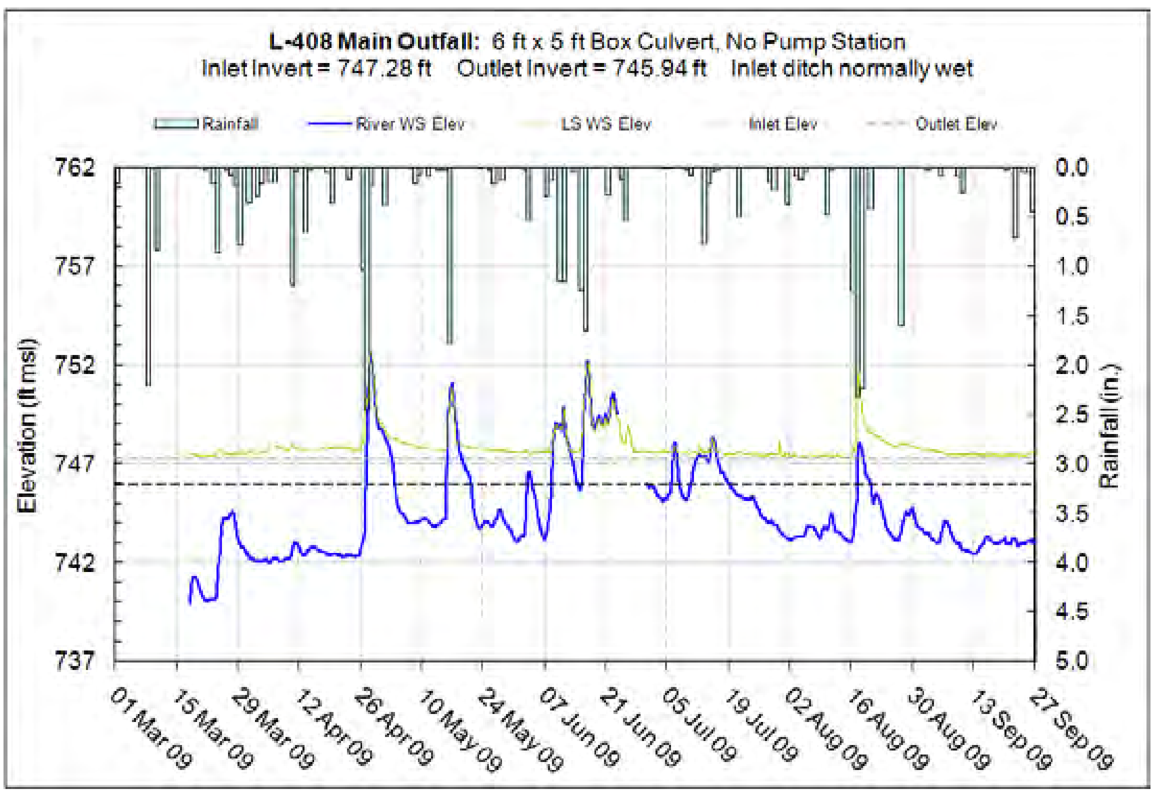

Figure 10.30.6 – Invert elevations, L-408

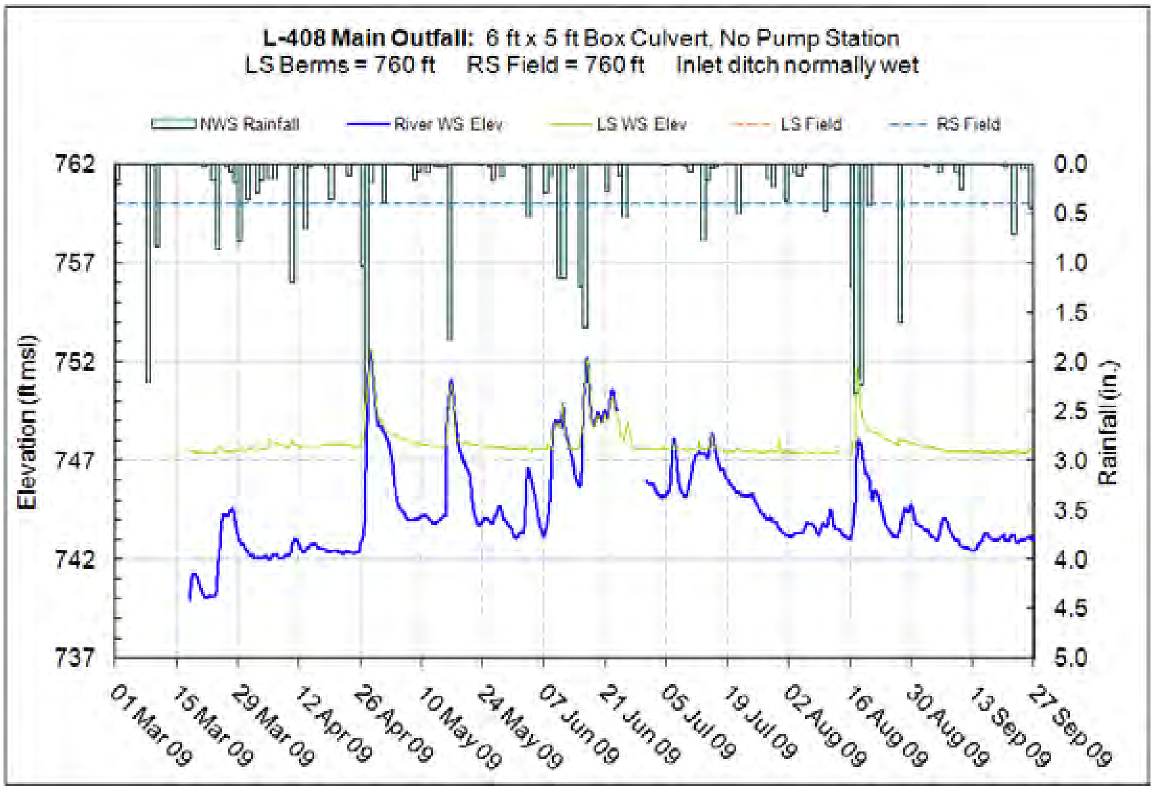

Figure 10.30.7 – Surveyed field elevations, L-408

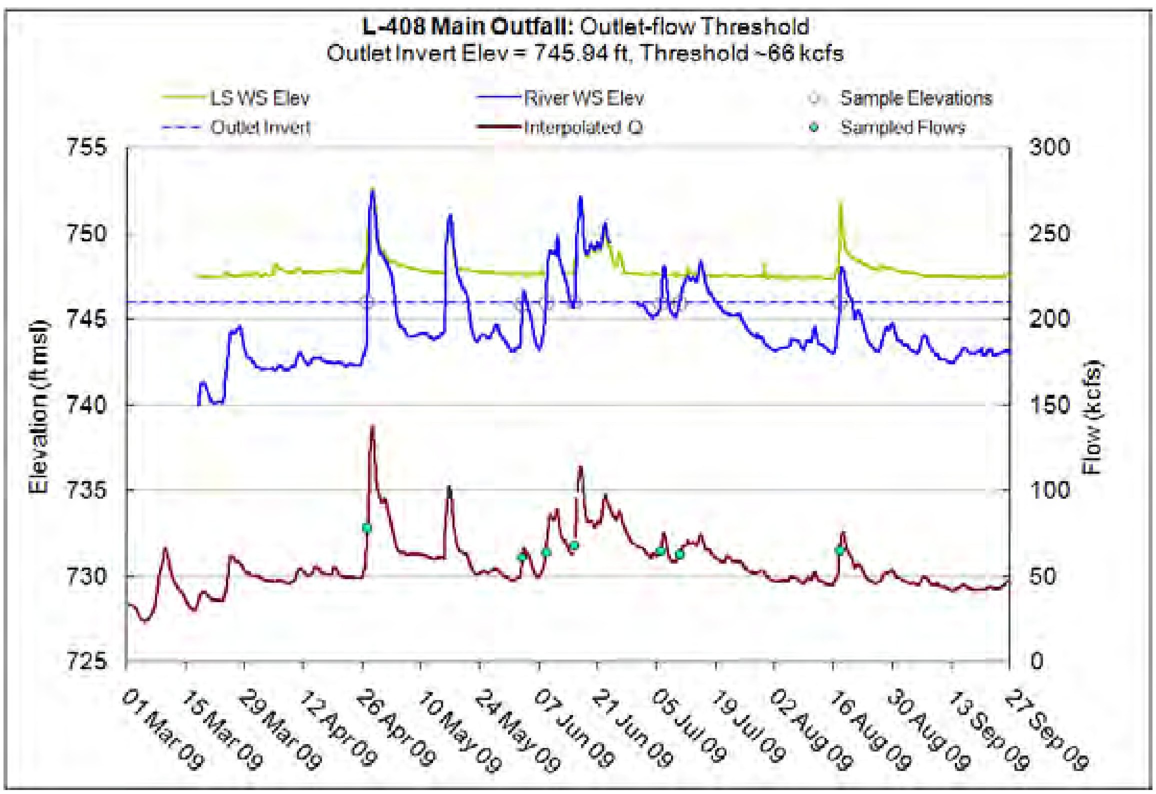

Figure 10.30.8 – Outlet-flow threshold, L-408

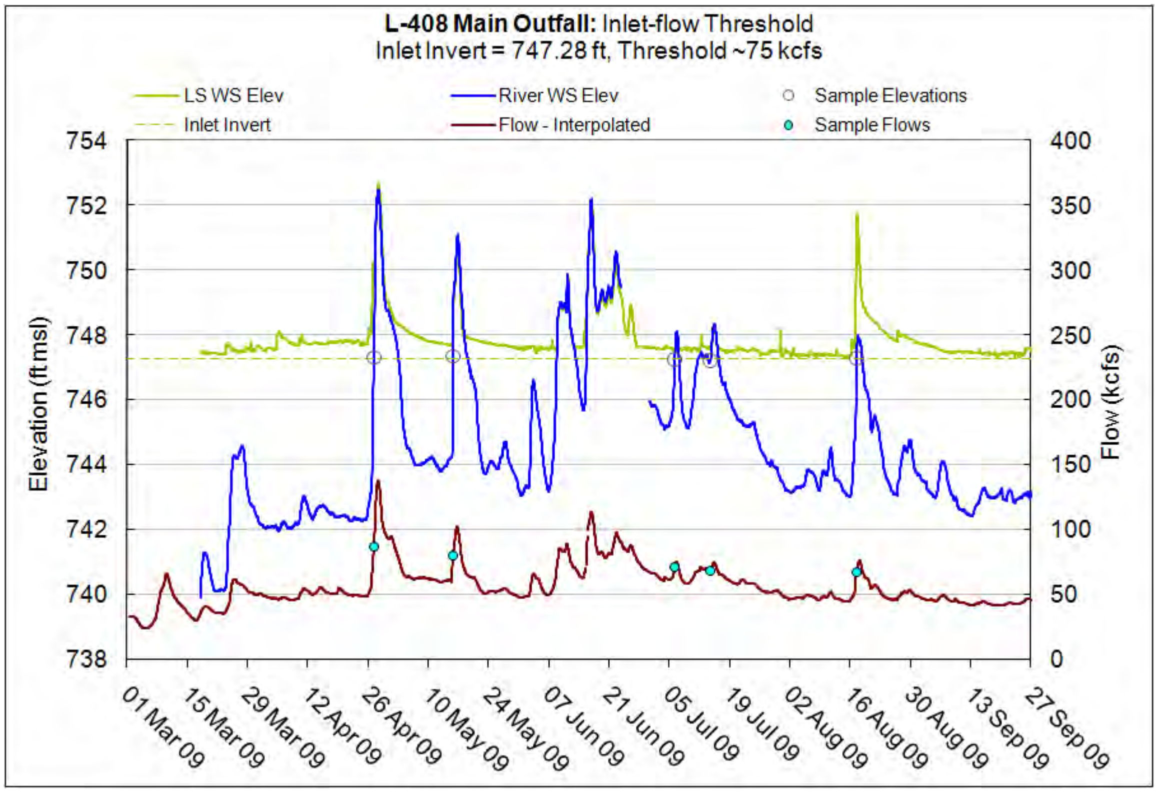

Figure 10.30.9 – Inlet-flow threshold, L-408

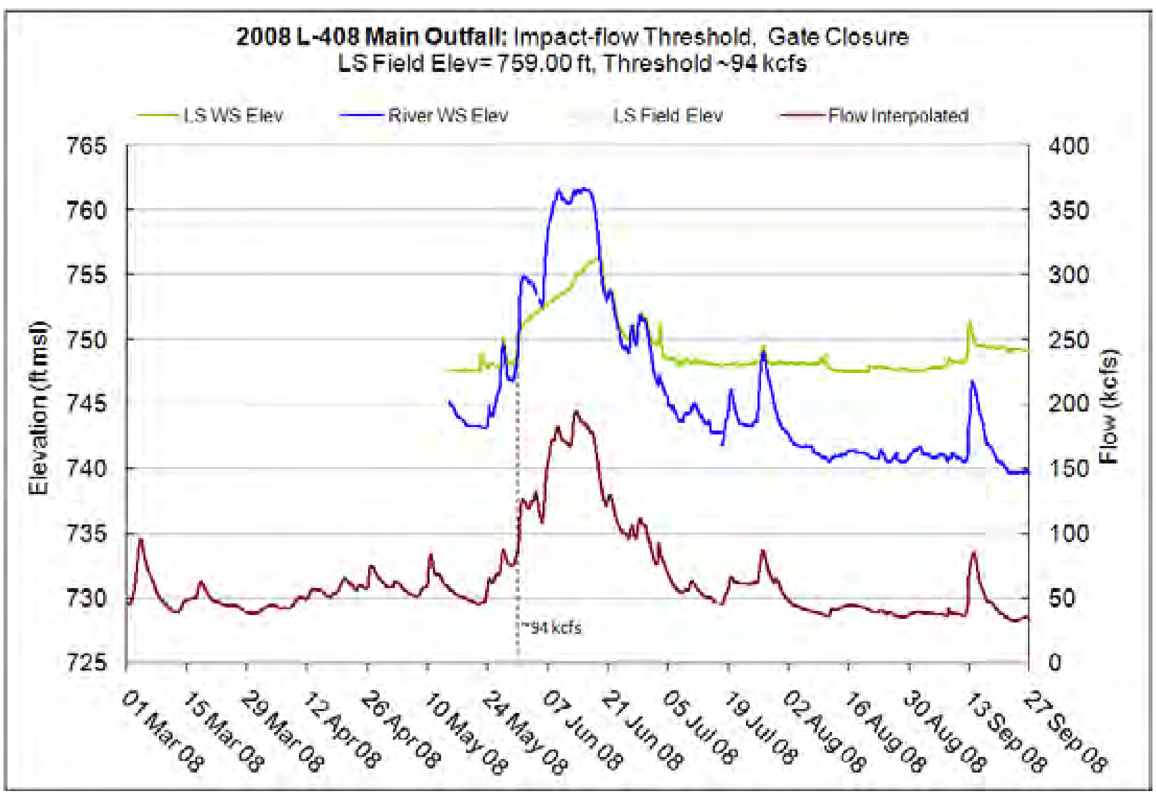

Figure 10.30.10 – Impact-flow threshold (gate closure), L-408 (2008 record)

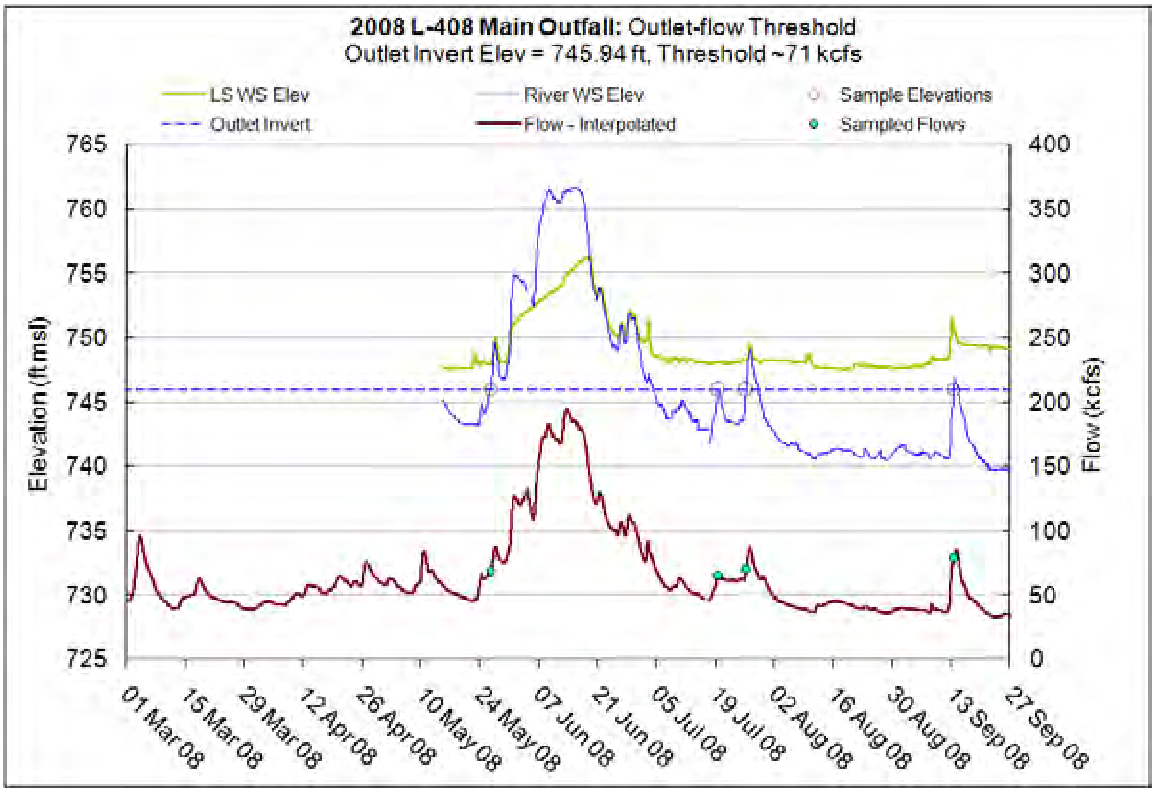

Figure 10.30.11 – Outlet-flow threshold, L-408 (2008 record)

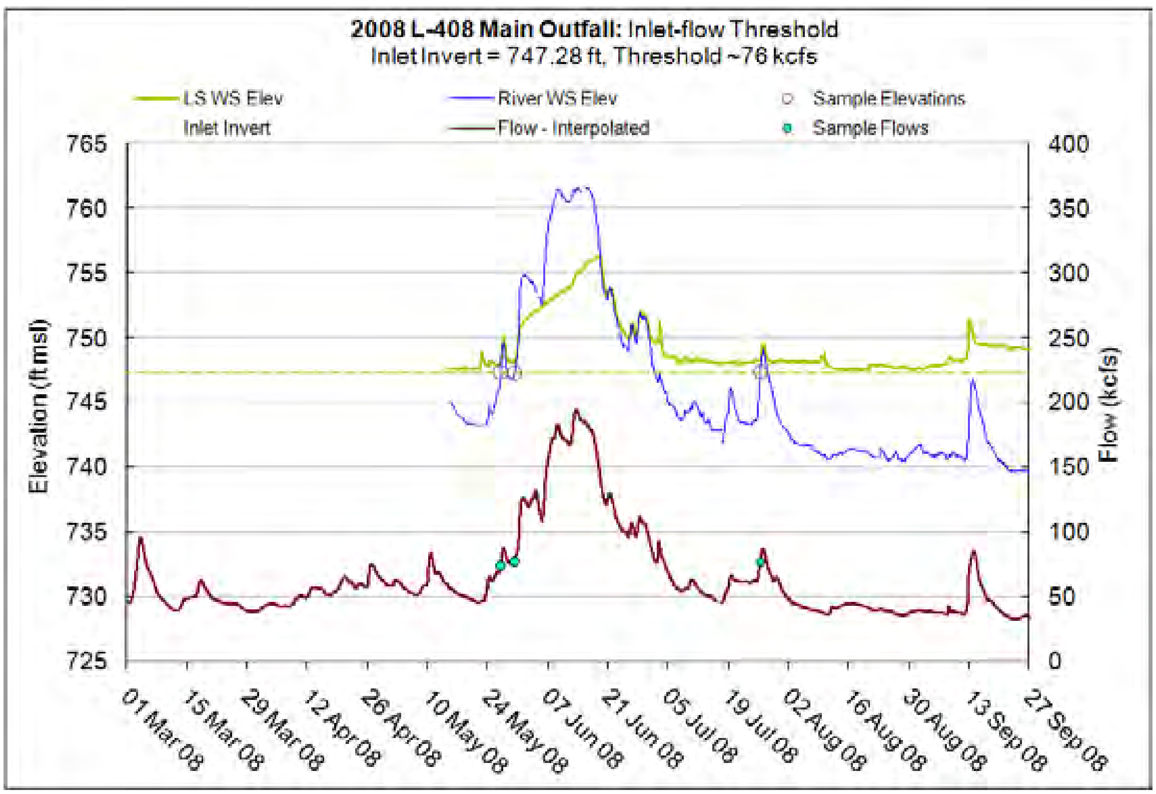

Figure 10.30.12 – Inlet-low threshold, L-408 (2008 record)

10.31 USGS Kansas City

The USGS Missouri River Kansas City gage is located downstream of Highway 169 on the right bank of the Missouri River at river mile 366.1 in Kansas City, MO (Figure 10.31.1). Data from this site are included to track the passage of the spring pulse down the main stem of the Missouri River. Flow reductions were made from dams tributary to the Missouri River to eliminate the created spring rise below Kansas City, MO. Figure 10.31.2 shows the location of the created spring rise based on navigation travel time to the site. The created spring rise was approximately 0.3 ft at this site above the reduced base flow. Figure 10.31.3 shows the full monitoring record with the travel time of the spring pulse noted.

Figure 10.31.1 – USGS Kansas City location

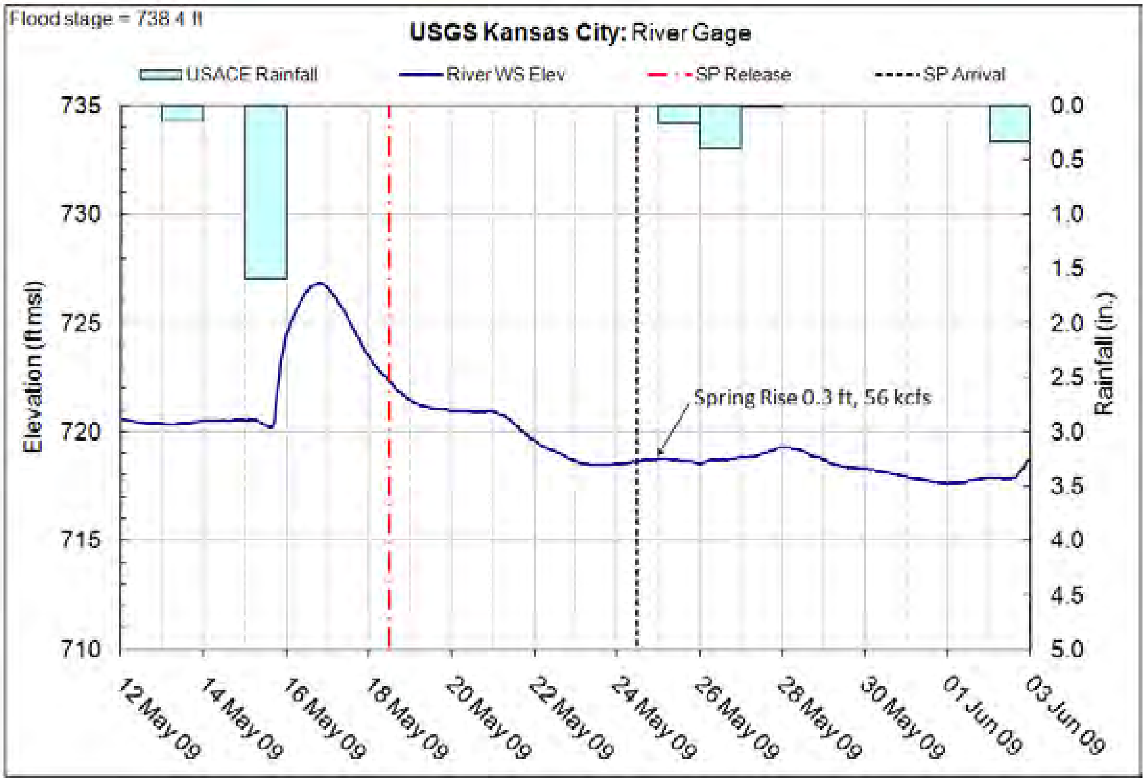

Figure 10.31.2 – Spring rise at Kansas City

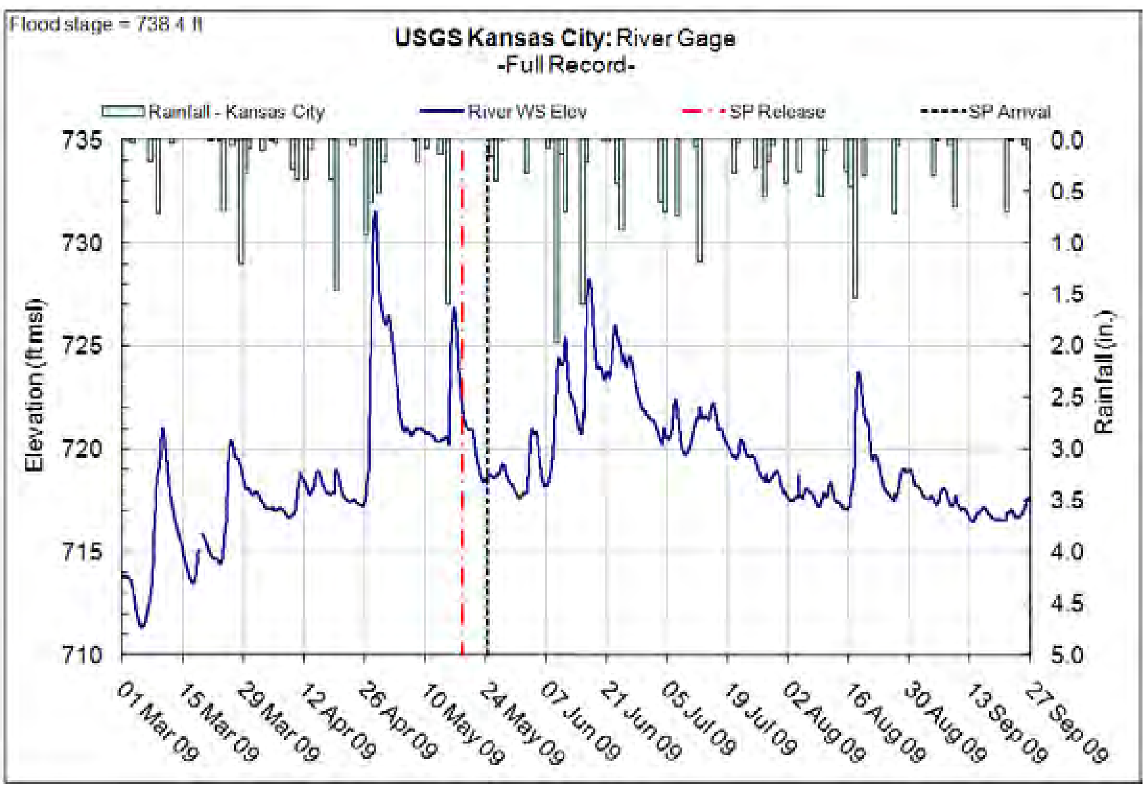

Figure 10.31.3 – Full monitoring record at Kansas City

10.32 USACE Napoleon

The USACE Missouri River Napoleon gage is located on the right bank of the Missouri River downstream of Napoleon, MO (Figure 10.32.1). Figure 10.32.2 shows the location of the created spring rise based on travel time to the site. The created spring rise was approximately 0.2 ft at this site. Figure 10.32.3 shows the full monitoring record with the travel time of the spring pulse noted. Flows went above flood stage (697.2 ft msl) three times during the full monitoring period.

Figure 10.32.1 – USACE Napoleon location

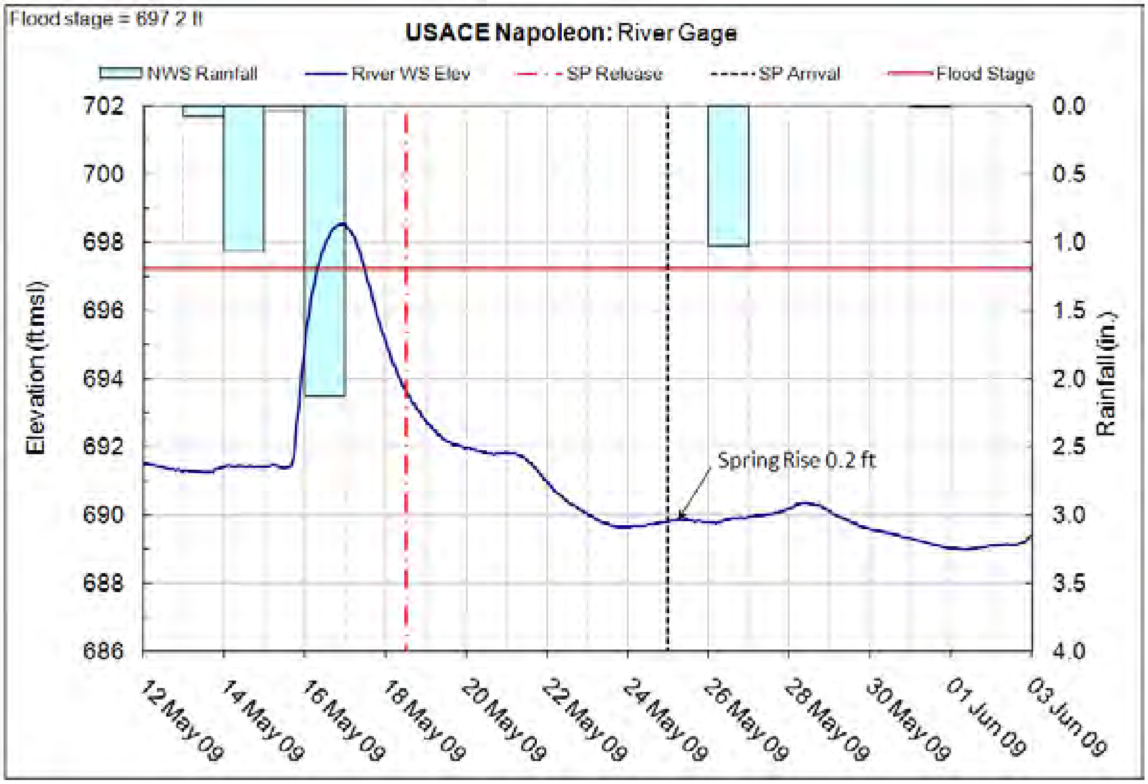

Figure 10.32.2 – Spring rise at Napoleon

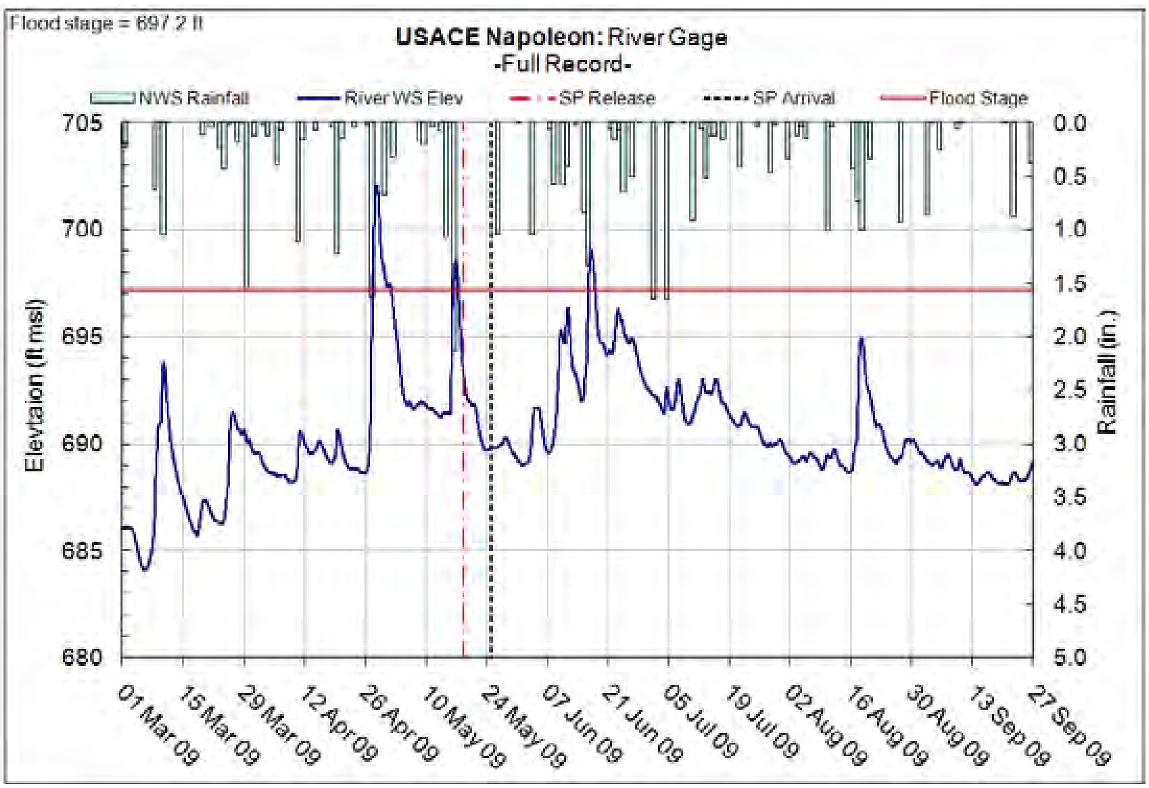

Figure 10.32.3 – Full monitoring record at USACE Napoleon

10.33 MO Valley DLD

The MO Valley DLD supplemental gage is located 2.5 river miles upstream of the MO Valley LD No. 1 supplemental site of 2008. The 2008 supplemental gage was located at RM 326.2; the 2009 supplemental gage is located at RM 328.7 on the north side of the Missouri River (Figure 10.33.1). The drainage structure at this site is a single 81.5-in. steel pipe with a slide-gated inlet (Figure 10.33.2, upper left) and a flap-gated outlet (Figure 10.33.2, lower left). The flap gate is weighted, which allows some control of the gate. The inlet-invert elevation of the structure is 690.80 ft and the outlet-invert elevation is 689.59 ft.

One supplemental gage was installed at this location. This gage was installed on the LS of the levee in the ponding area near the inlet of the drainage structure (Figure 10.33.3). Riverside elevations were obtained from the automatic USACE Napoleon gage installed at RM 328.7 (Figure 10.33.3).

Field elevations were surveyed in 2009. The surveyed LS field elevation of the wheat fields bordering the drainage ponds is 695.3 ft. Fields rise to 704 ft upstream of the drainage ponds on the landward side of the pools. The RS field elevation is 700.5 ft. Fields on the RS were plowed in May 2009 and may have been planted with corn. The excavated drainage ditch on the riverside of the levee doglegs out to the Missouri River about 1 mile downstream of the drainage structure. The LS surveyed field elevation of 695.3 ft and the RS surveyed field elevation of 700.5 ft were used in the figures and analysis.

Flows were estimated at the site by lagging the flow record of USGS Kansas City and USGS Waverly to the site based on peaks and then interpolating flows based on river miles. The nearest USGS gage with flow data upstream of the site is USGS Kansas City.

Results and Discussion

§ Table 10.33.1 summarizes the results for the May 2009 created spring rise, and the Missouri River flows estimated to reach the outlet and inlet of the site's drainage structure.

§ Table 10.33.2 summarizes the socioeconomic impacts produced by the natural spring rises at the site in May 2009. The site was not monitored in 2008. Landside flooding occurred for 2 days, riverside flooding occurred for 1 day, and gate closures ranged between 0.1 to 4.1 days.

§ Figure 10.33.4 shows the spring pulse release on May 18 and its arrival time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise in stage created by the May spring pulse was approximately 0.1 ft. Based on the attenuation analysis, the spring pulse accounts for 1.0 kcfs of the total 59-kcfs Missouri River flow at this river mile, or 1.7% of the total flow.

§ Figure 10.33.5 shows the full period of the monitoring record with the time of the spring pulse's release and its arrival time at the site shown.

§ Figure 10.33.6 shows the full period of the monitoring record with the inlet and outlet inverts of the drainage structures.

§ Figure 10.33.7 shows the 2009 surveyed field elevations for the RS and LS gages.

§ Figure 10.33.8 combines the information gained on the inlet and outlet inverts and the field elevations to separate out possible socioeconomic impacts produced by natural spring rises during the monitoring period. Minor LS and RS flooding and gate closers appear to have occurred. Minor flooding possibly into the wheat fields bordering the drainage ponds on the LS of the site appears to have occurred for a short duration (2

days). Minor flooding on the riverside of the site might have also occurred and was also of a short duration (1 day).

- Figure 10.33.9 shows the determination of impact flow thresholds for overbank flooding on the RS of the levee. The RS field appears to have experienced minor flooding when flow in the Missouri River reached 157 kcfs at the site and 136 kcfs at the Kansas City gage upstream.
- Figure 10.33.10 shows the determination of impact flow thresholds for flooding on the LS of the levee. Minor flooding appears to have occurred when flow in the Missouri River reached 105 kcfs at the site or 81 kcfs at the Kansas City gage upstream. It is likely, based on the estimated gate-closure threshold of 100 kcfs, flooding was due to interior runoff not being able to drain and not due directly to high flows on the Missouri River.
- Figure 10.33.11 shows the determination of the impact thresholds for gate closures. Gate closure could have been produced by water pressures on the flap gate or controlled by the landowner. Gate closure occurred when the Missouri River flows at the site were approximately 100 kcfs or 90 kcfs at the Kansas City gage upstream of the site.
- Figure 10.33.12 shows the estimation of the outlet-flow threshold at the site. Flows in the Missouri River need to reach about 58 kcfs at the site or 55 kcfs at Kansas City to each the outlet invert elevation.
- Figure 10.33.13 shows the estimation of the inlet-flow threshold. Flows in the Missouri River need to reach 64 kcfs at the site or 62 kcfs at Kansas City to reach the inlet invert.

Conclusions

No socioeconomic impacts were created by the created spring rise in May 2009. Based on the attenuation analysis, the spring pulse accounts for 1.0 kcfs of the total 59-kcfs Missouri River flow at this river mile, or 1.7% of the total flow. Minor flooding and gate closures were the two identified socioeconomic impacts from natural spring rises. Flooding on the landside occurred once in the record and the duration of the flooding was about 2 days. Gate closures appear to have occurred three times in the period of record and their durations ranged from 2.1 to 14.6 days. The total time of gate closures was 18.8 days, which is 1.2 days shorter than in 2008 at the 2008 Missouri Valley site 2.5 RM upstream. Gates were closed for a total period of 20 days in 2008 while the longest duration of closure in 2009 was 5.3 days.

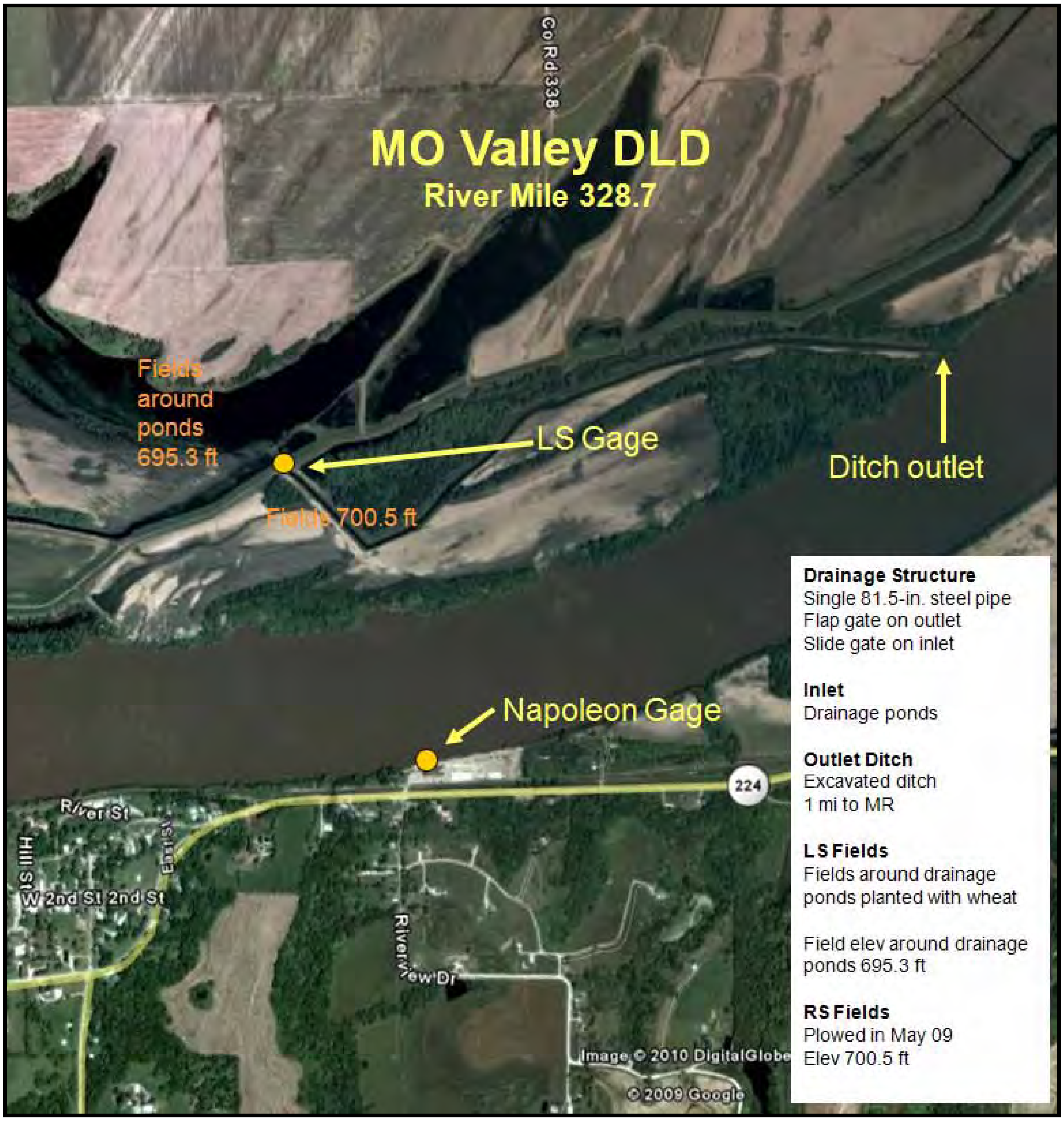

Figure 10.33.1 – MO Valley DLD location

Table 10.33.1 – MO Valley DLD results

Spring Pulse from Gavins Point Dam	*May-09*	*Mar-08*
Created spring rise, ft	0.1	-
Estimated created spring rise flow, kcfs	1.2	-
Estimated MR flow, kcfs	59	-
% of MR flow	2	-

Outlet--Flow Threshold	*May-09*	*Mar-08*
Elev, ft	689.59	-
Estimated flow at site, kcfs	58	-
Flow at nearest US gage, kcfs	55	-
Nearest US gage	Kansas City	-

Inlet-Flow Threshold	*May-09*	*Mar-08*
Elev, ft	690.80	-
Estimated flow at site, kcfs	64	-
Flow at nearest US gage, kcfs	62	-
Nearest US gage	Kansas City	-

Table 10.33.2 – MO Valley DLD NSR socioeconomic impacts

2009 Natural Spring Rise Impacts	*LS Flooding*	*RS Flooding*	*Gate Closure*
Elev, ft	695.3	700.5	694.7
Total impact duration, dy	2	1	0.1 – 4.1
Estimated flow at site, kcfs	105*	157	100
Flow at nearest US gage, kcfs	81*	136	90
Nearest US gage	Kansas City	Kansas City	Kansas City

*The gage closes at 100 kcfs, so it is likely flooding was due to interior runoff not being able to drain and not due directly to high flows on the Missouri River

Figure 10.33.2 – MO Valley DLD site. Inlet slide gate and landside gage (top left). Outlet with flap gate and weight (top right). Top of levee looking landward at interior ponds and fields beyond (bottom left). Outlet drainage ditch (bottom right).

Figure 10.33.3 – MO Valley DLD gages. Landside data logger by slide gate inlet (left). River DCP located in Corps of Missouri River Area Office at Napoleon (left).

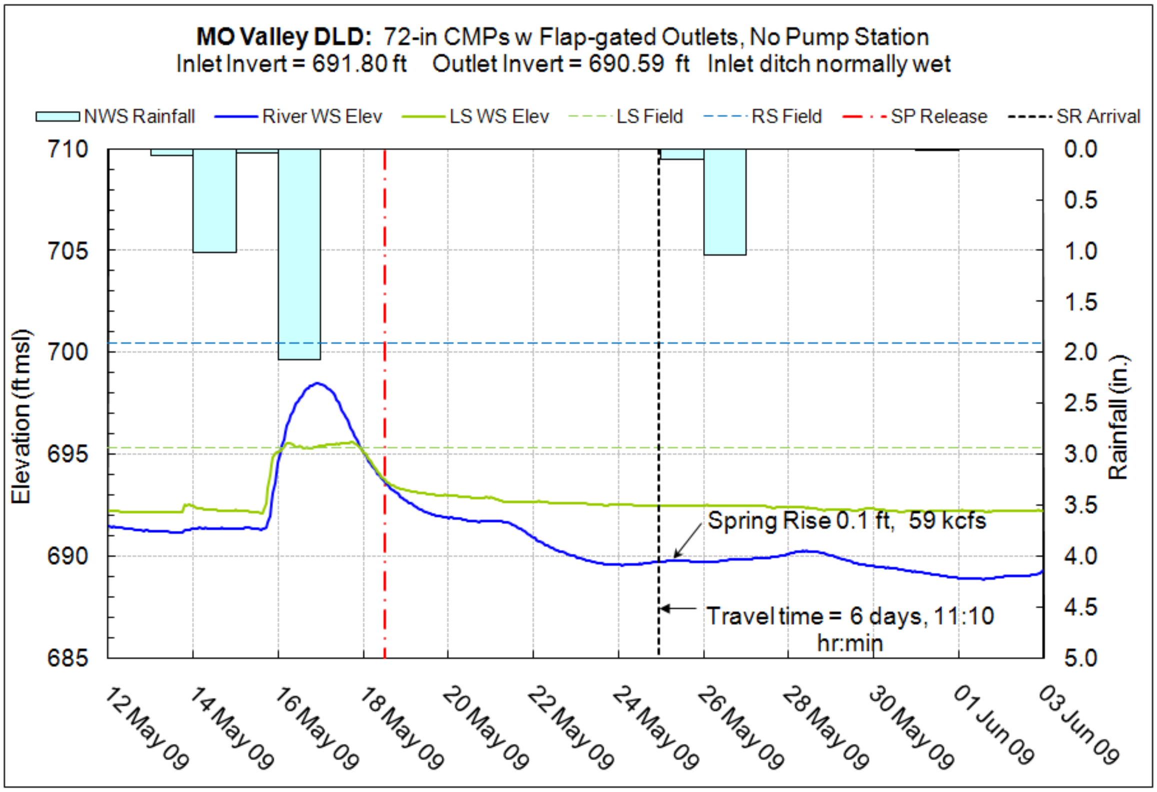

Figure 10.33.4 – Spring rise at MO Valley DLD

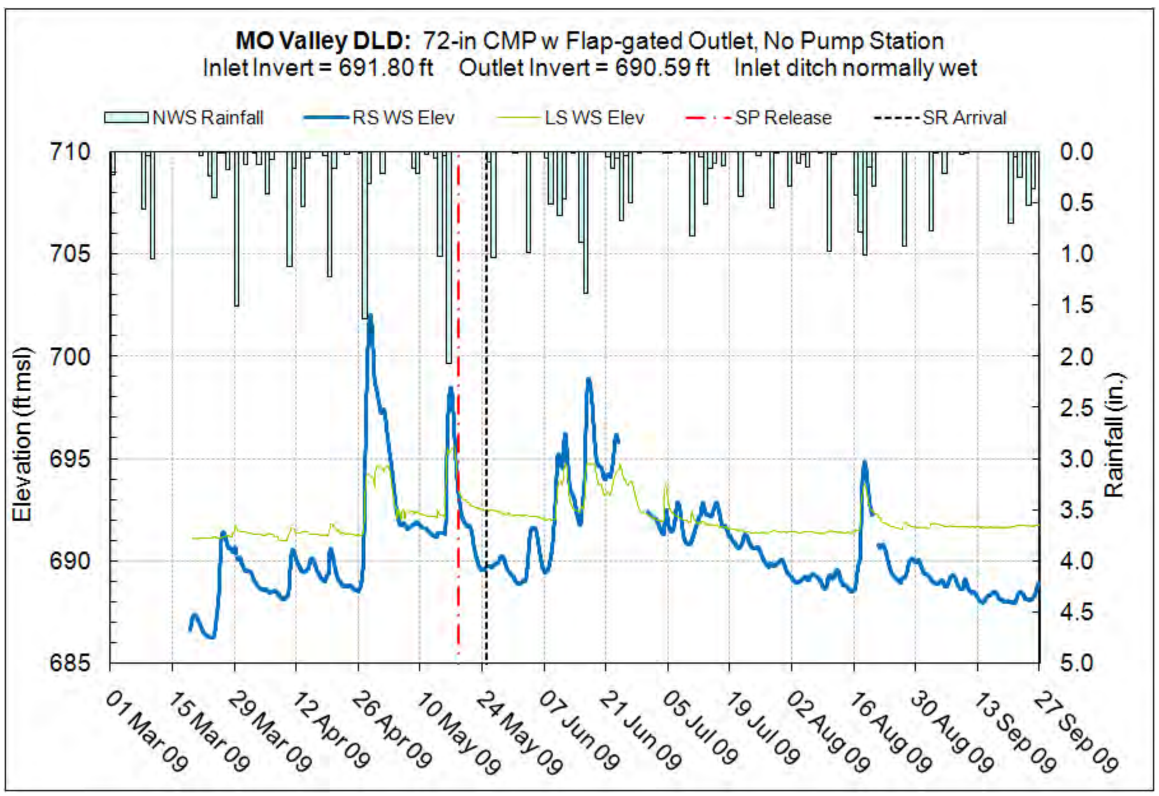

Figure 10.33.5 – Full monitoring record at MO Valley DLD

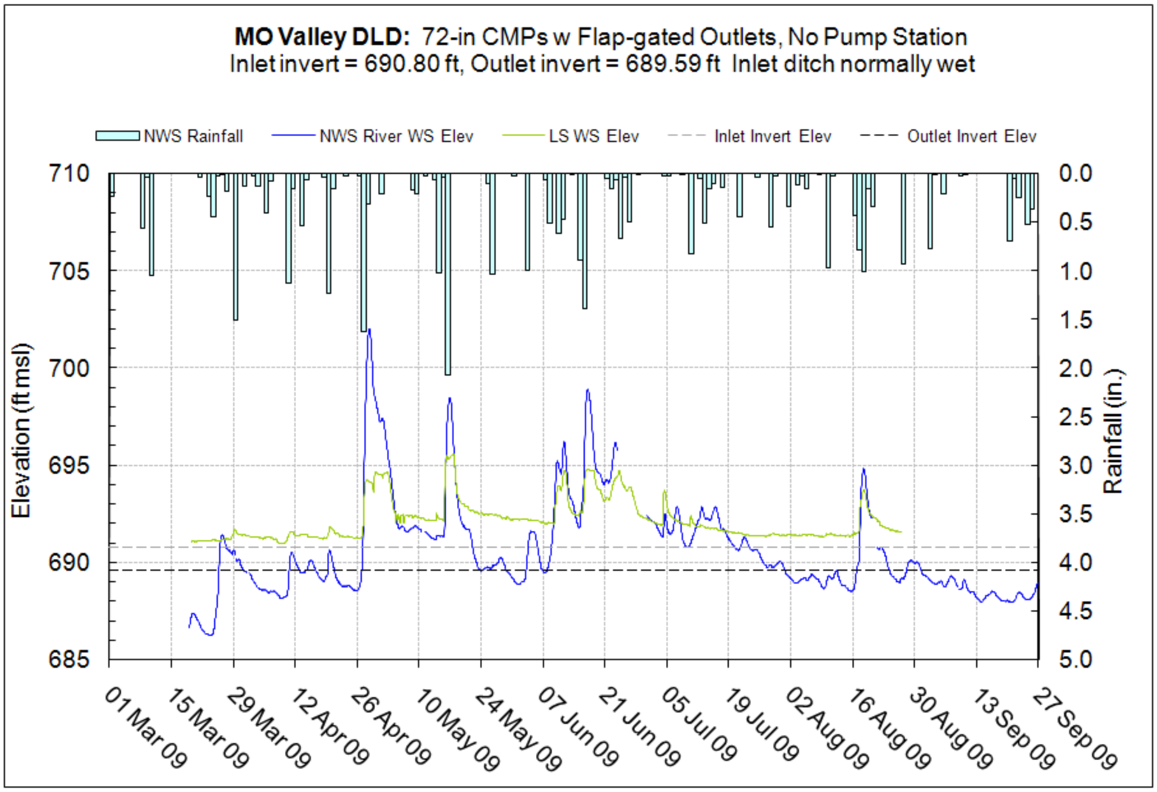

Figure 10.33.6 – Invert elevations, MO Valley DLD

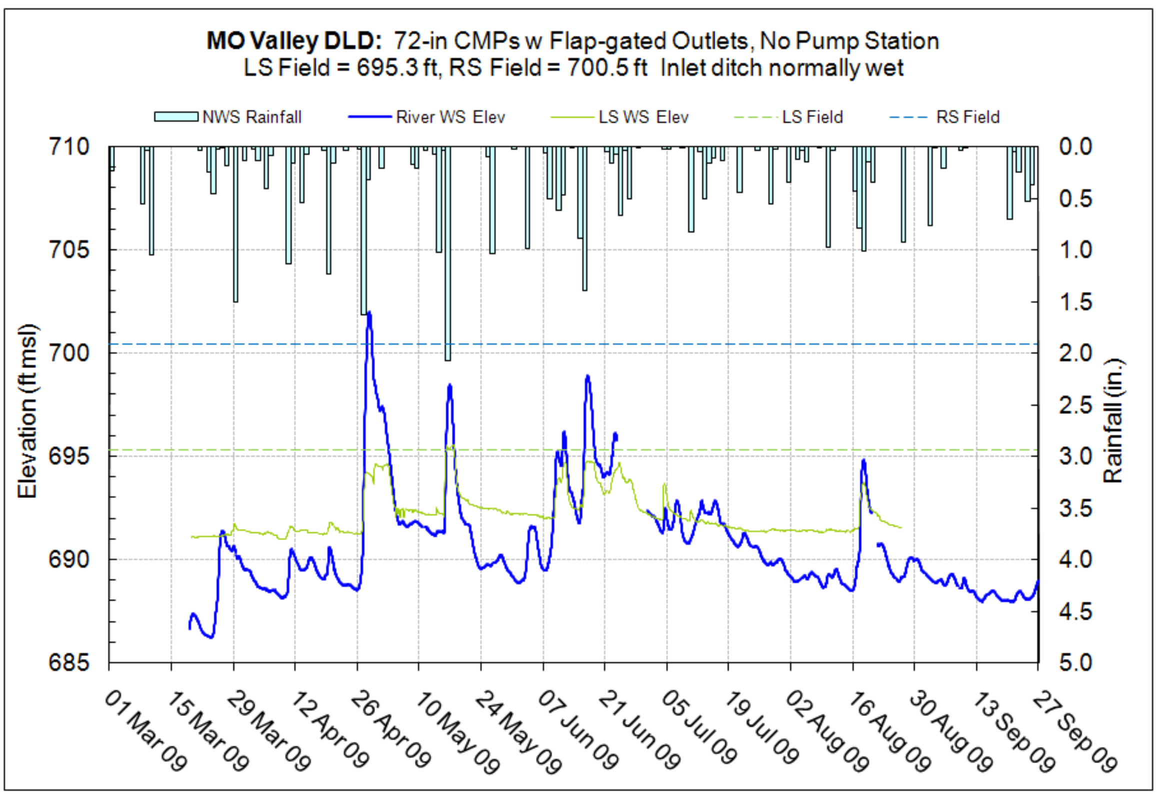

Figure 10.33.7 – Surveyed field elevations, MO Valley DLD

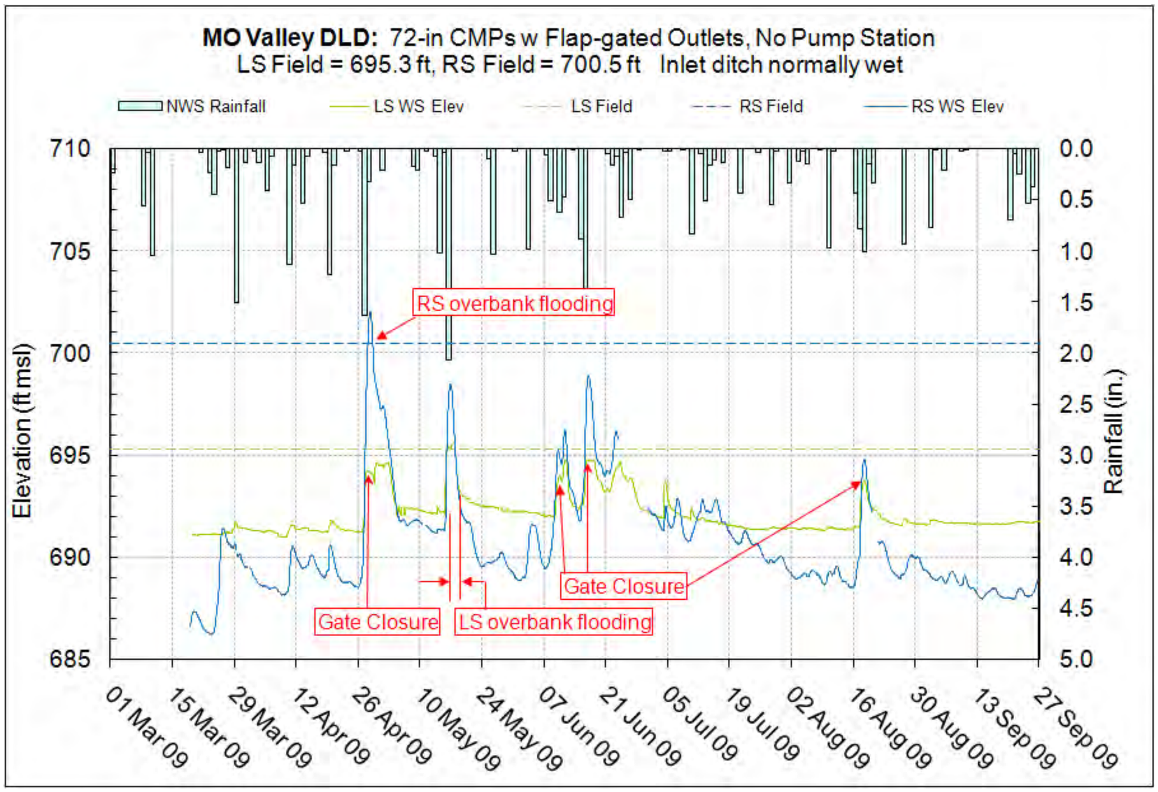

Figure 10.33.8 – NSR Socioeconomic impacts, MO Valley DLD

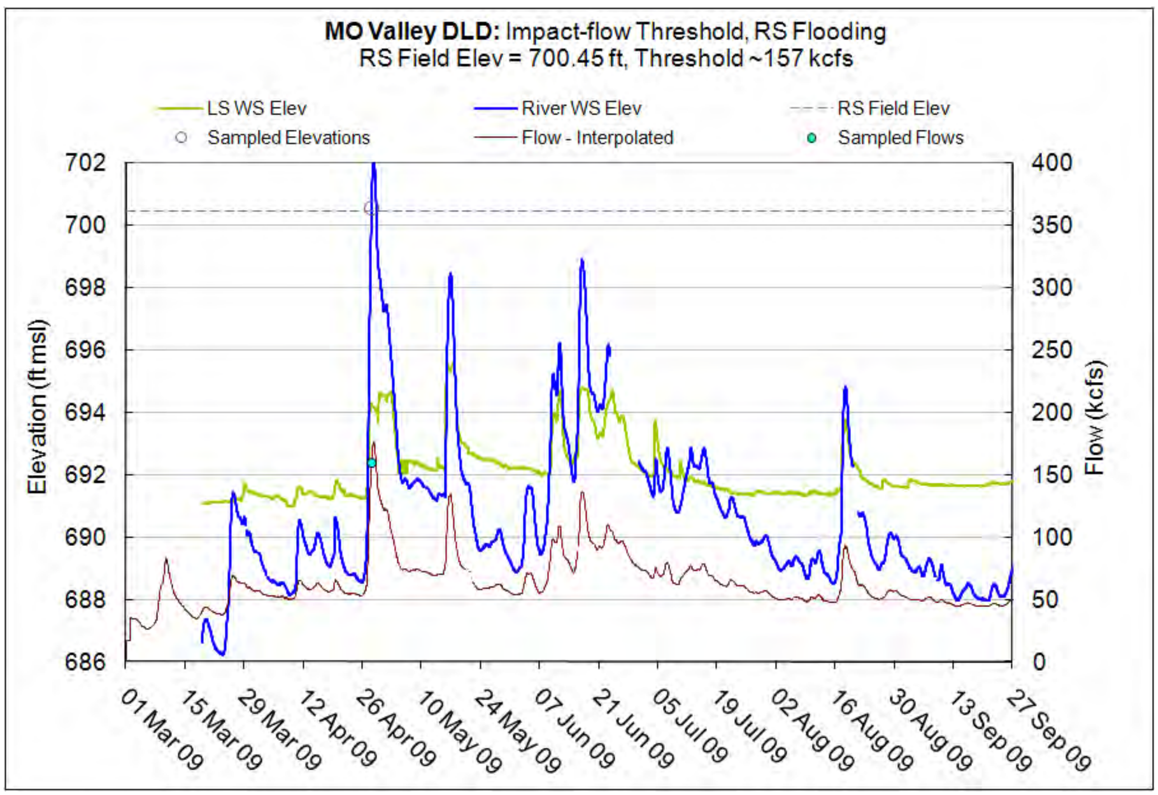

Figure 10.33.9 – Impact-flow threshold (RS overland flooding), MO Valley DLD

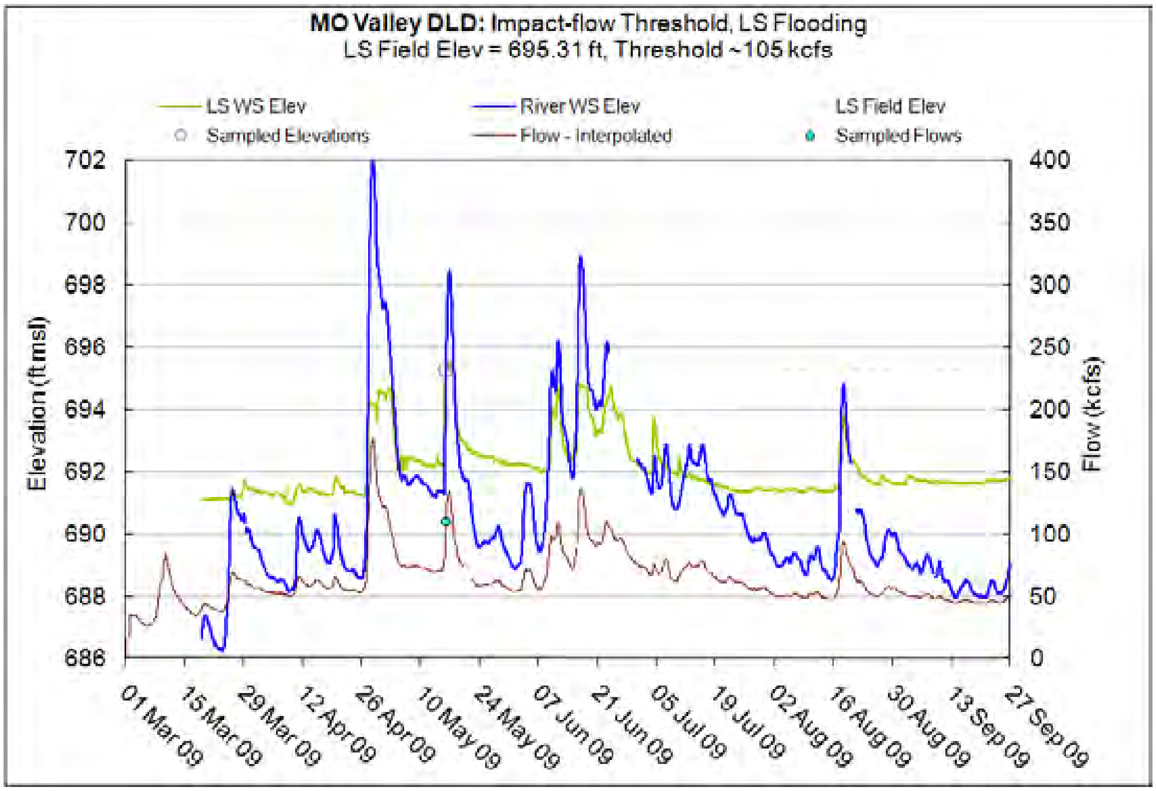

Figure 10.33.10 – Impact-flow threshold (LS overland flooding), MO Valley DLD

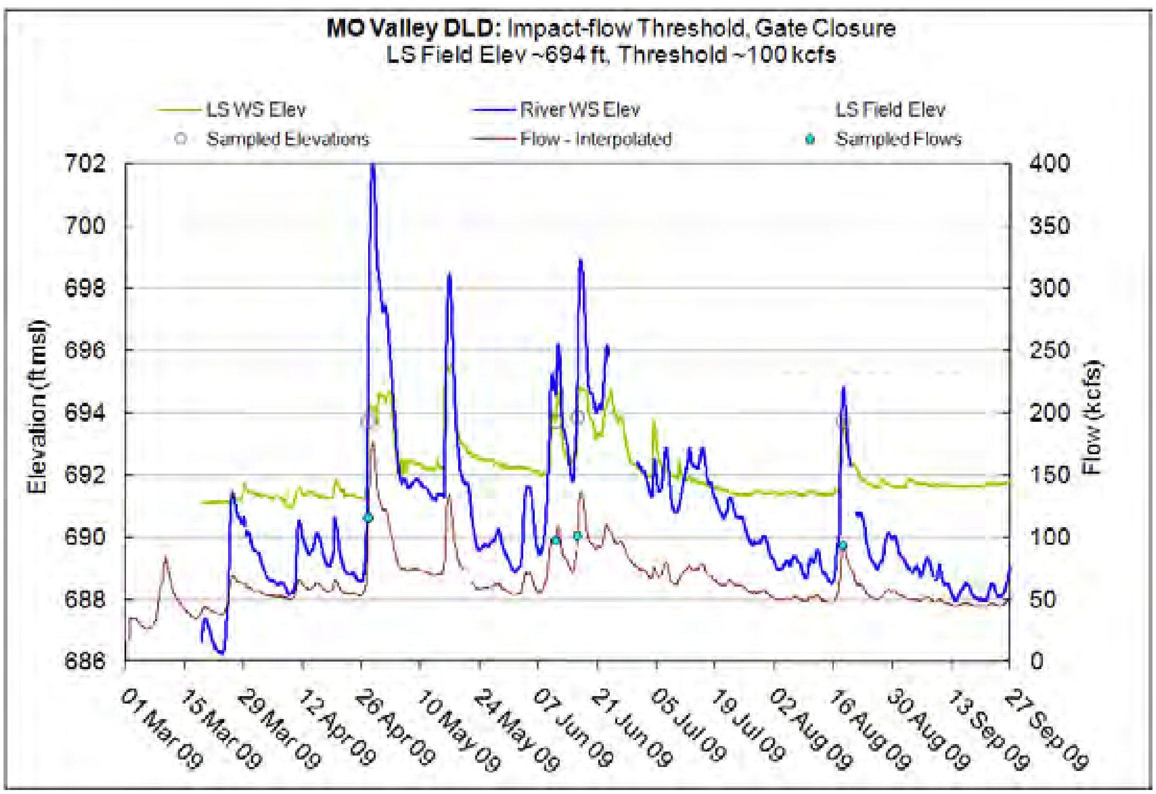

Figure 10.33.11 – Impact-flow threshold (gate closure), MO Valley DLD. The threshold varies in this case because the owner has some control of the gate.

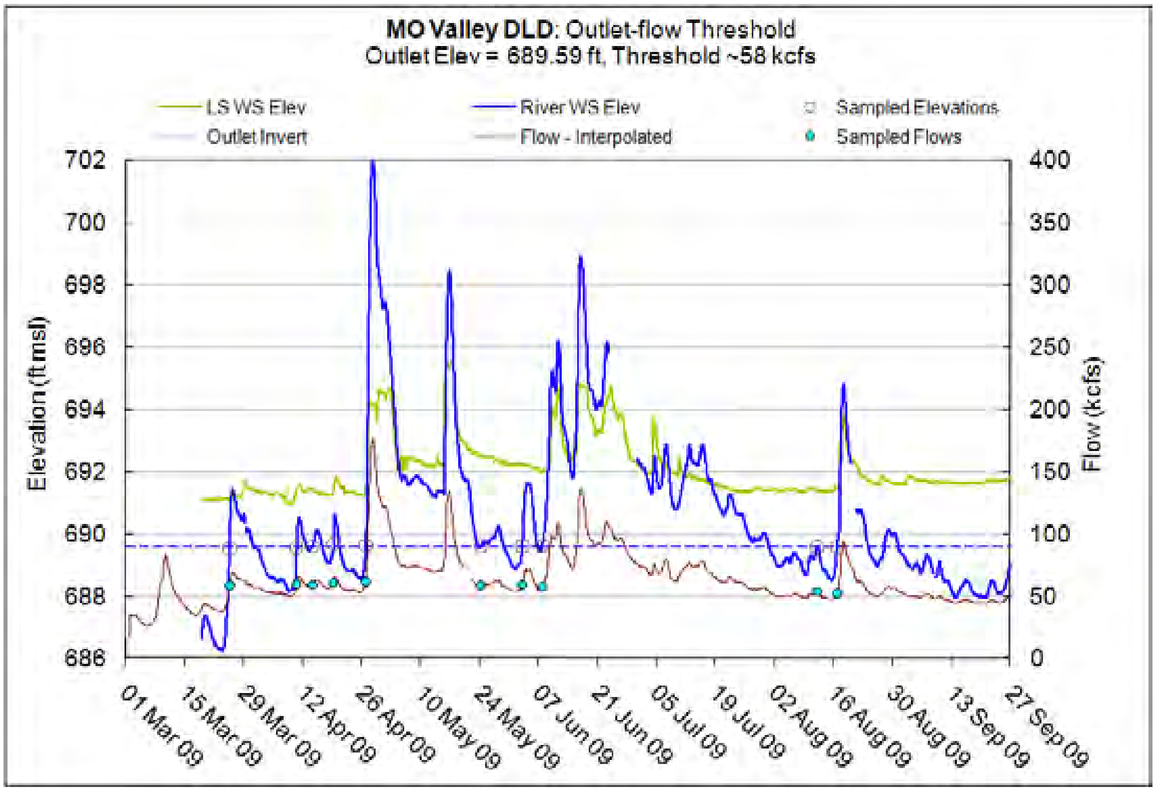

Figure 10.33.12 – Outlet-flow threshold, MO Valley DLD

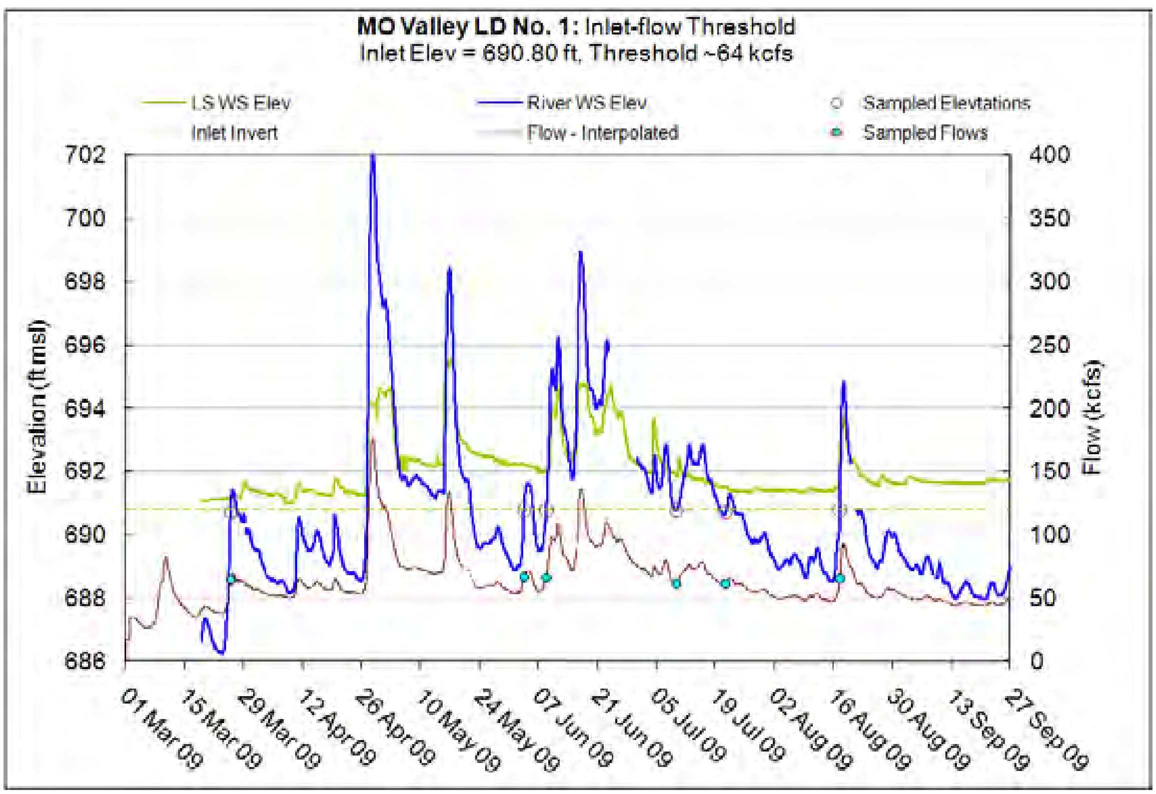

Figure 10.33.13 – Inlet-flow threshold, MO Valley DLD

10.34 USGS Waverly

The USGS Missouri River Waverly gage is located upstream of the Highway 65 bridge on the right bank of the Missouri River at river mile 293.4 (Figure 10.34.1) near Waverly, MO. Figure 10.34.2 shows the location of the created spring rise based on travel time to the site. The created spring rise at this site could not be identified. Figure 10.34.3 shows the full monitoring record with the travel time of the spring pulse noted. Flows went above flood stage three times during the period of record. All flood durations were less than 1 week and were all due to natural spring rises.

Figure 10.34.1 – USGS Waverly location

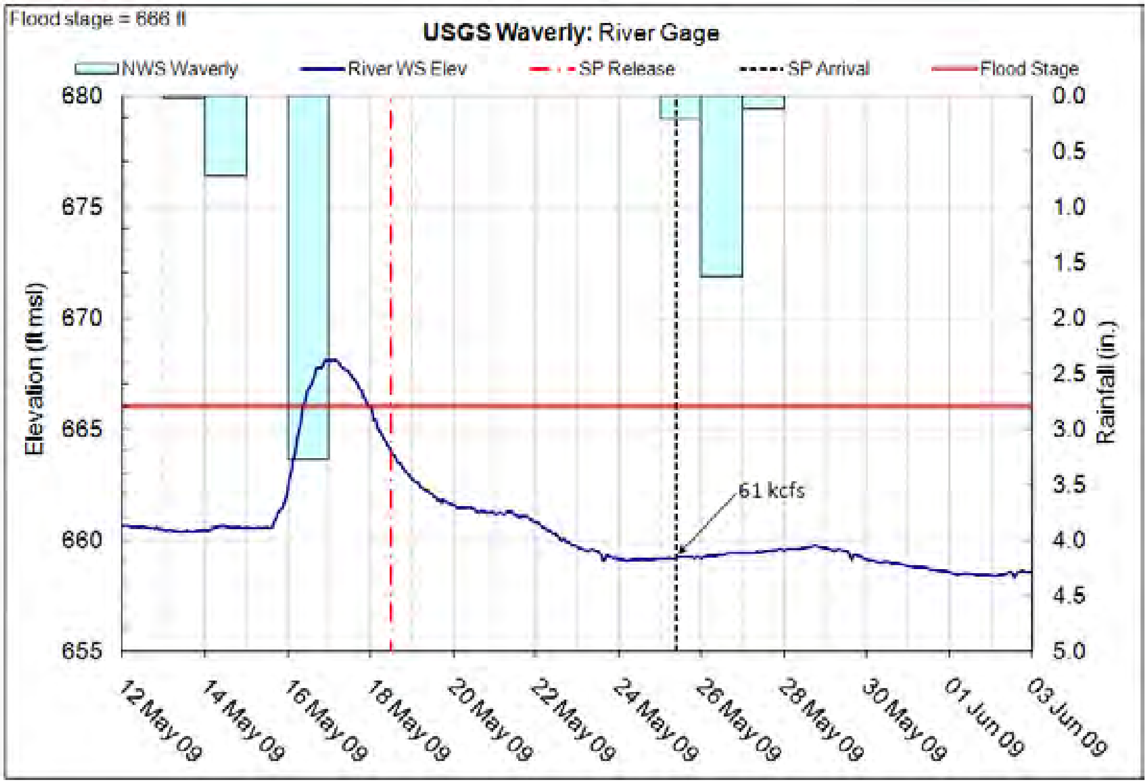

Figure 10.34.2 – Spring rise at USGS Waverly

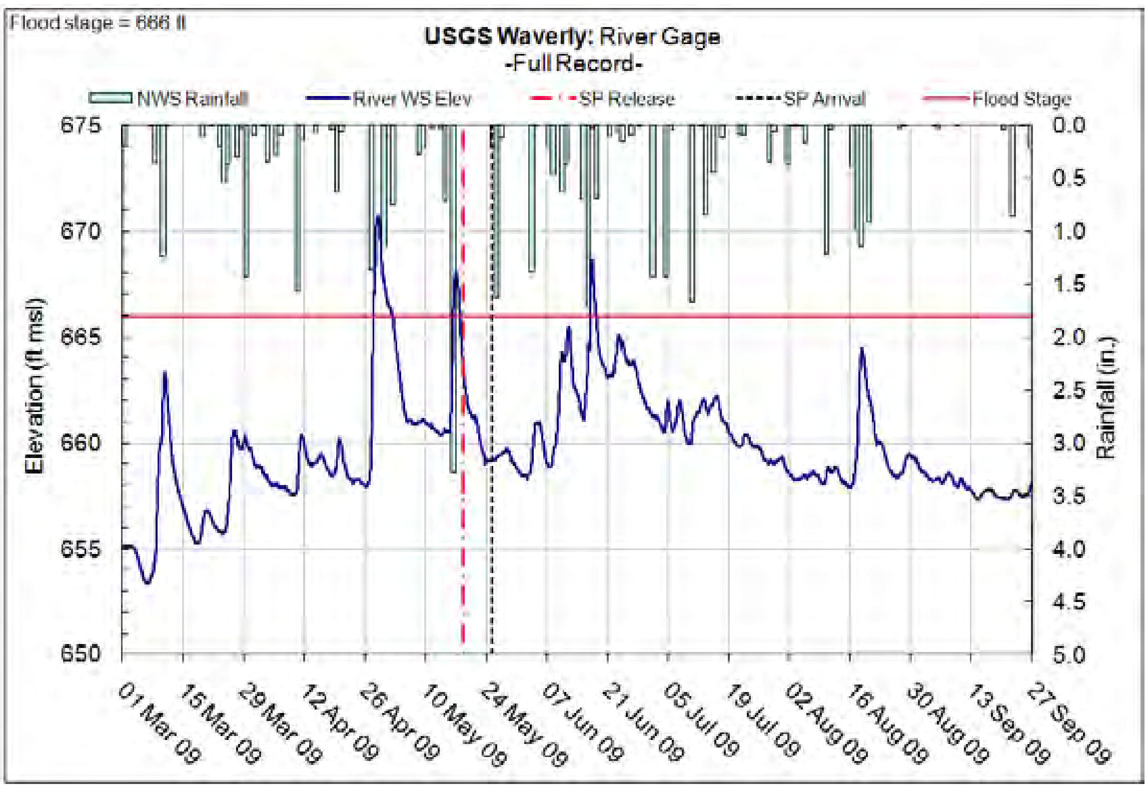

Figure 10.34.3 – Full monitoring record at USGS Waverly

10.35 Brunswick Terminal

Brunswick Terminal is located at RM 256.3 on the north bank of the Missouri River in Carroll County, MO in the Dewitt Bend of the river (Figure 10.35.1). This site is a temporary DCP and is housed in a gage house attached to the riverward side of an electrical shack (Figure 10.35.2). Elevation data collected at this site is used as a reference for sites downstream. Flows were estimated at the site by lagging the flow records of USGS Waverly to the site.

Results and Discussion

- Table 10.35.1 summarizes the results for the May 2009 created spring rise. This site was not monitored in 2008.
- Figure 10.35.3 shows the spring pulse release and its arrival time to the site. The rise created by the May spring pulse could not be identified. Based on the attenuation analysis, the spring pulse accounts for 0.1 kcfs of the total 62-kcfs Missouri-River flow at this river mile, or 0.2% of the total flow.
- Figure 10.35.4 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site shown.

Conclusions

Based on the attenuation analysis, the spring pulse accounts for 0.1 kcfs of the total 62-kcfs Missouri-River flow at this river mile, or 0.2% of the total flow.

Figure 10.35.1 – Brunswick Terminal location

Figure 10.35.2 – Brunswick Terminal DCP. DCP gage house attached to electrical shack at main dock (left). Gage house looking toward terminal storage building (right).

Table 10.35.2 – Brunswick Terminal results

Spring Pulse from Gavins Point Dam	*May-09*	*Mar-08*
Created spring rise, ft	0	n.a.
Estimated created spring rise flow, kcfs	0.1	n.a.
Estimated MR flow at site, kcfs	62	n.a.
% of MR flow	0.2	n.a.

n.a. Not monitored in 2008

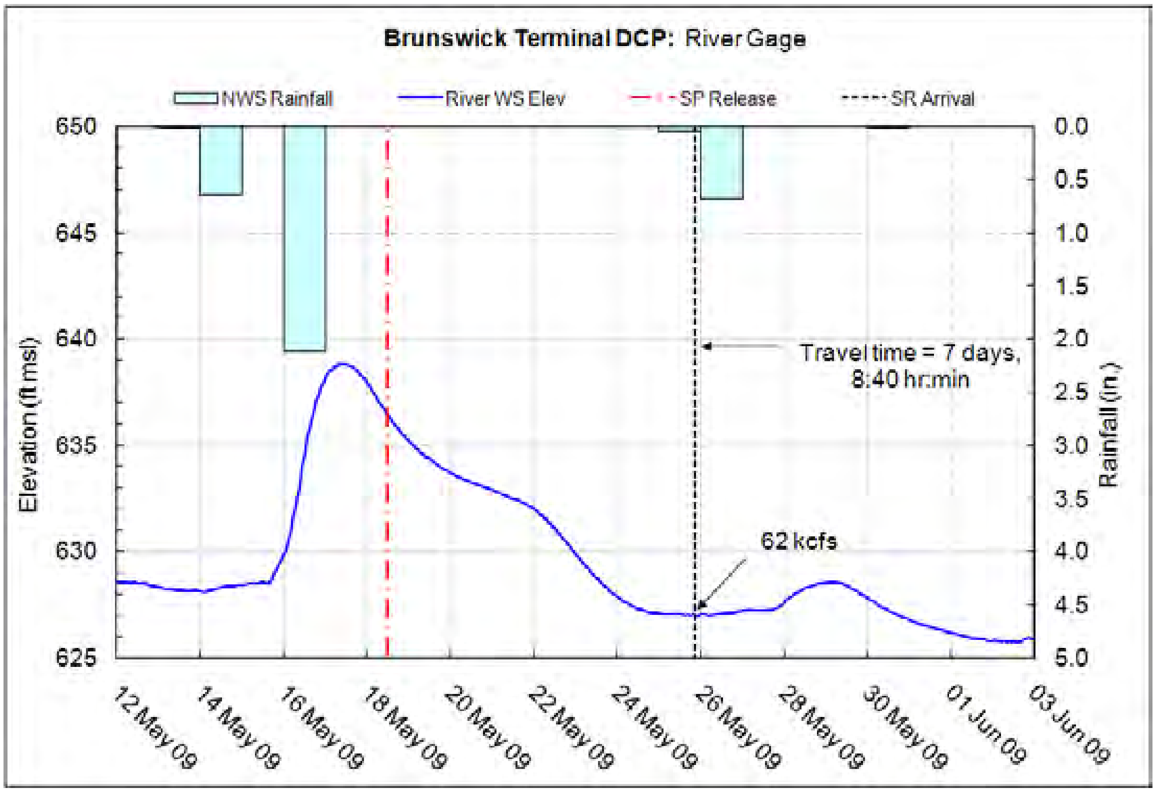

Figure 10.35.3 – Spring rise at Brunswick Terminal

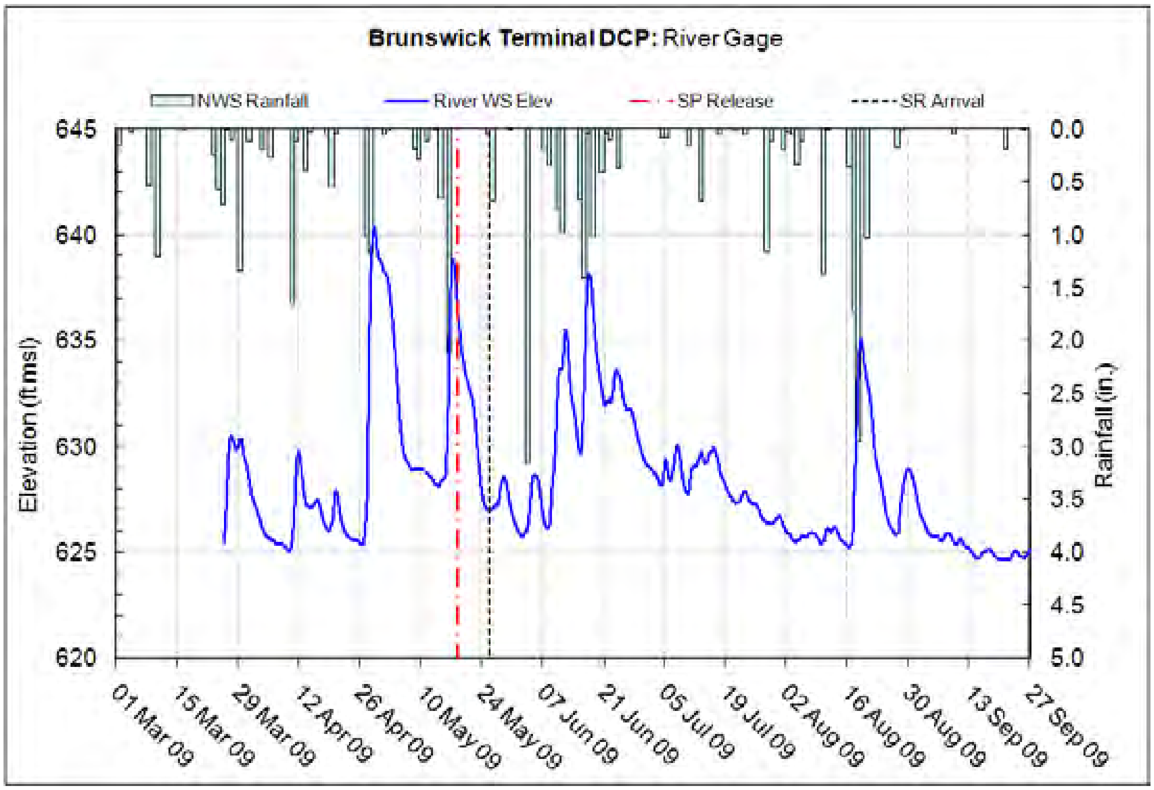

Figure 10.35.4 – Full monitoring record at Brunswick Terminal

10.36 Dewitt DLD

The Dewitt DLD supplemental gage is located at RM 255.3 in the Dewitt Bend of the Missouri River on the left bank in Carroll County, MO (Figure 10.36.1). The drainage structure at this site is a single 24-in steel pipe culvert through the main levee with an open inlet and a flap-gated outlet (Figure 10.36.2). The inlet-invert elevation of the structure is 629.26 ft, and the outlet-invert elevation is 627.86 ft. The elevation of the levee crest above the culvert is 646.06 ft. The site has no pump station, and the outlet opens directly to the Missouri River. The drainage ditch is excavated below the elevation of the fields but has no berms.

Two data loggers were installed to monitor water surface elevations in 2009. The LS data logger was installed in the excavated interior ditch near the inlet. The RS data logger was installed in the Missouri River near the outlet of the structure. Field elevations were surveyed in 2009. The average interior field elevation surveyed 100 ft from the interior drainage ditch and 100 ft from the main levee was 635.9 ft. Flows were estimated at the site by lagging the flow record of USGS Waverly to the site.

Results and Discussion

- § Table 10.36.1 summarizes the results for the May 2009 created spring rise, and the Missouri River flows estimated to reach the outlet and inlet of the site's drainage structure.
- § Table 10.20.2 summarizes the socioeconomic impacts produced by natural spring rises at the site in May 2009. Durations of gate closures ranged from 2 days to almost 5 days.
- § Figure 10.36.3 shows the spring pulse release on May 18 and its arrival time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise created by the May spring pulse at this site was imperceptible. Based on the attenuation analysis, the spring pulse accounts for about 0.1 kcfs of the total 62-kcfs Missouri River flow at this river mile, or 0.2% of the total flow.
- § Figure 10.36.4 shows the full period of the monitoring record with the time of the spring pulse's release and its arrival time at the site shown.
- § Figure 10.36.5 shows the March through August 2009 portion of the monitoring record with the inlet and outlet inverts of the drainage structures.
- § Figure 10.36.6 shows the 2009 surveyed field elevations for the riverside (RS) and landside (LS) gages.
- § Figure 10.36.7 combines the information gained on the inlet- and outlet-inverts and the field elevations to separate out possible socioeconomic impacts produced by natural spring rises during the monitoring period.
- § Figure 10.36.8 shows the estimation of the impact thresholds for gate closures based on socioeconomic impacts identified in Figure 10.36.7. Note that water elevations did not become high enough on the LS of the levee to create overbank flooding.
- § Figure 10.36.9 shows the estimation of the outlet-flow threshold. Missouri River flows must be 64 kcfs or higher to reach the outlet of the drainage structure.
- § Figure 10.36.10 show the estimation of the inlet-flow threshold. Missouri River flows must be 71 kcfs or higher to reach the inlet invert of the drainage structure.

Conclusions

No socioeconomic impacts were produced by the May 2009 created spring rise. Gate closures appear to have occurred when the Missouri River reached an interpolated flow of 122 kcfs at the site. Based on the attenuation analysis, the spring pulse accounts for 0.1 kcfs of the total 62-kcfs Missouri River flow at this river mile, or 0.2% of the total flow.

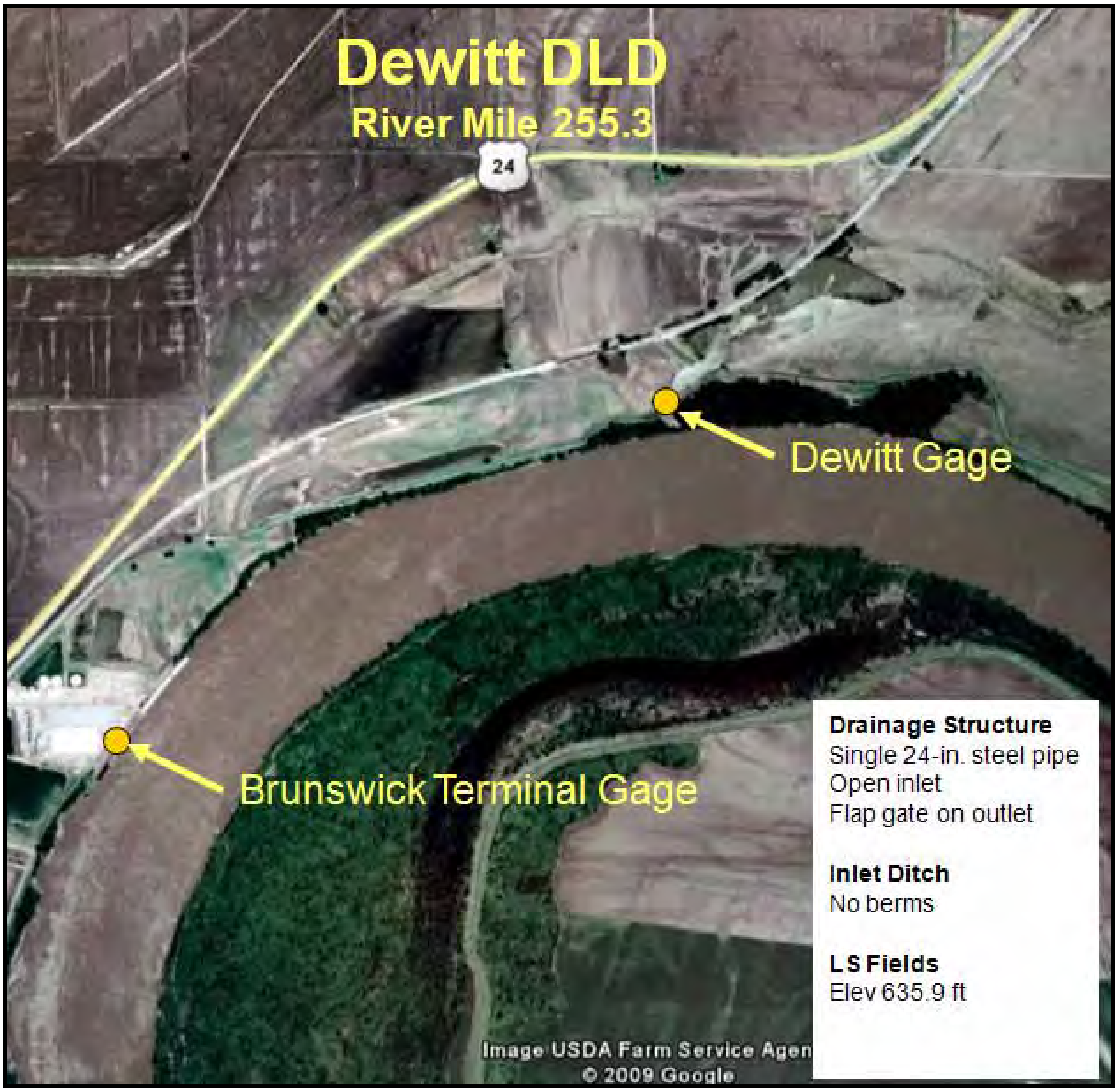

Figure 10.36.1 – Dewitt DLD location

Figure 10.36.2 – Dewitt DLD site and gages. Data logger next to 24-in. culvert inlet pipe through main levee (top left). Culvert outlet with flap gate through main levee (top right). Top view of outlet and river (center left). Landside data logger in inlet ditch with interior fields (center right). Inlet ditch along tieback levee to railroad grade (bottom right). River data logger on bank looking US toward Brunswick Terminal (bottom right).

Table 10.36.1 – Dewitt DLD results

Spring Pulse from Gavins Point Dam		
	May-09	***Mar-08***
Created spring rise, ft	0	-
Estimated created spring rise flow, kcfs	0.1	-
Estimated MR flow at site, kcfs	62	-
% of MR flow	0.2	-

Outlet-flow Threshold		
	May-09	***Mar-08***
Elev, ft	627.86	-
Estimated MR flow at site, kcfs	64	-

Inlet-flow threshold		
	May-09	***Mar-08***
Elev, ft	627.86	-
Estimated MR flow at site, kcfs	71	-

Table 10.36.2 – Dewitt DLD NRS socioeconomic impacts

2009 Natural Spring Rise Impacts			
	LS Flooding	***RS Flooding***	***Gate Closure***
Elev, ft	no flooding	no flooding	n.a.
Impact duration, dy	-	-	2.0 – 4.7
Estimated MR flow at site, kcfs	-	-	89

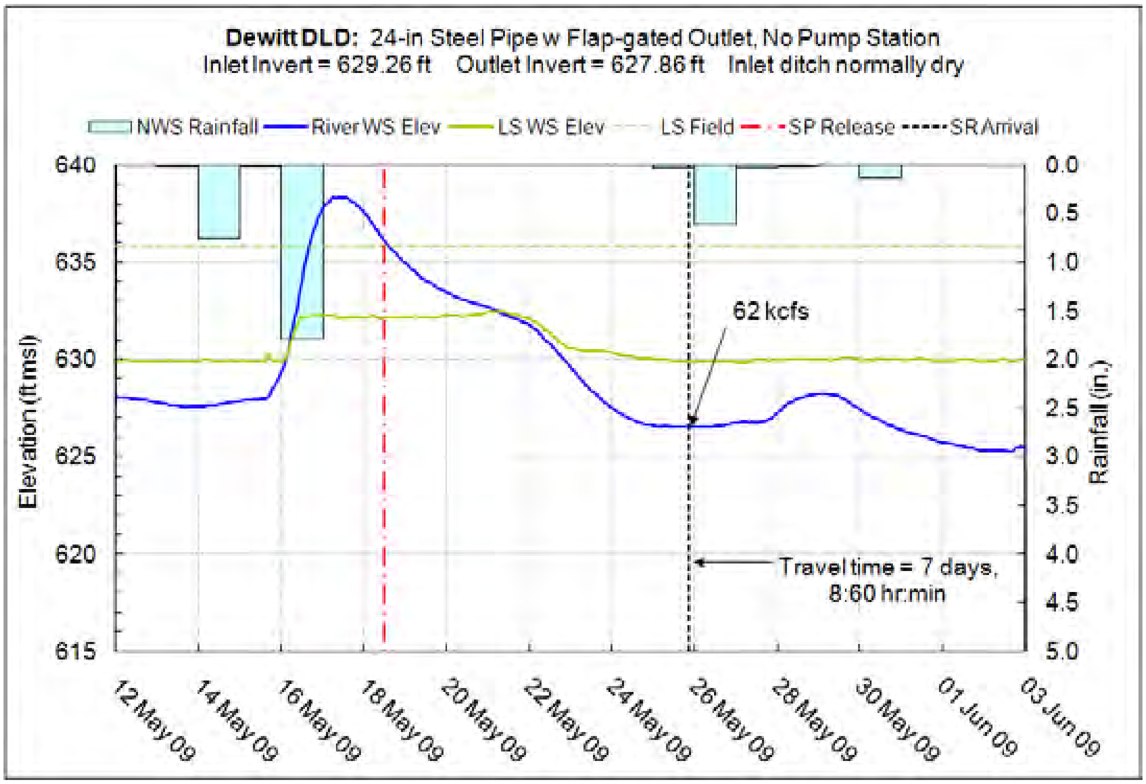

Figure 10.36.3 – Spring rise at Dewitt DLD

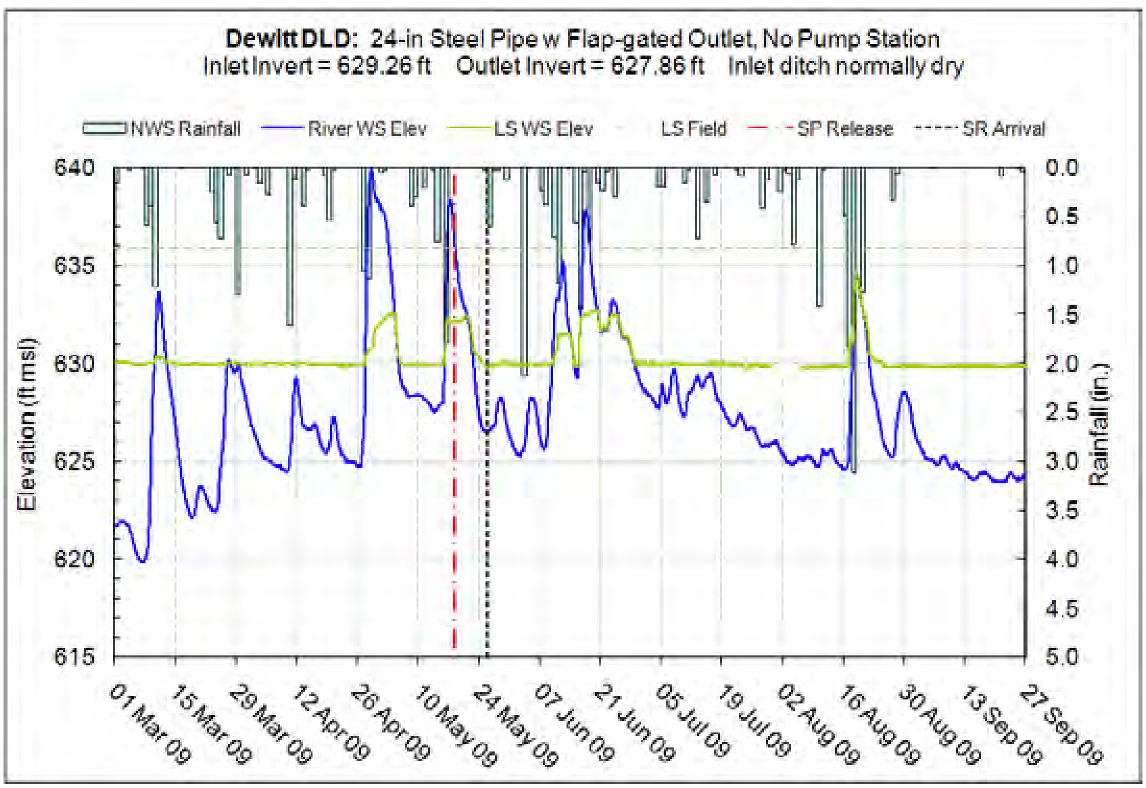

Figure 10.36.4 – Full monitoring record at Dewitt DLD

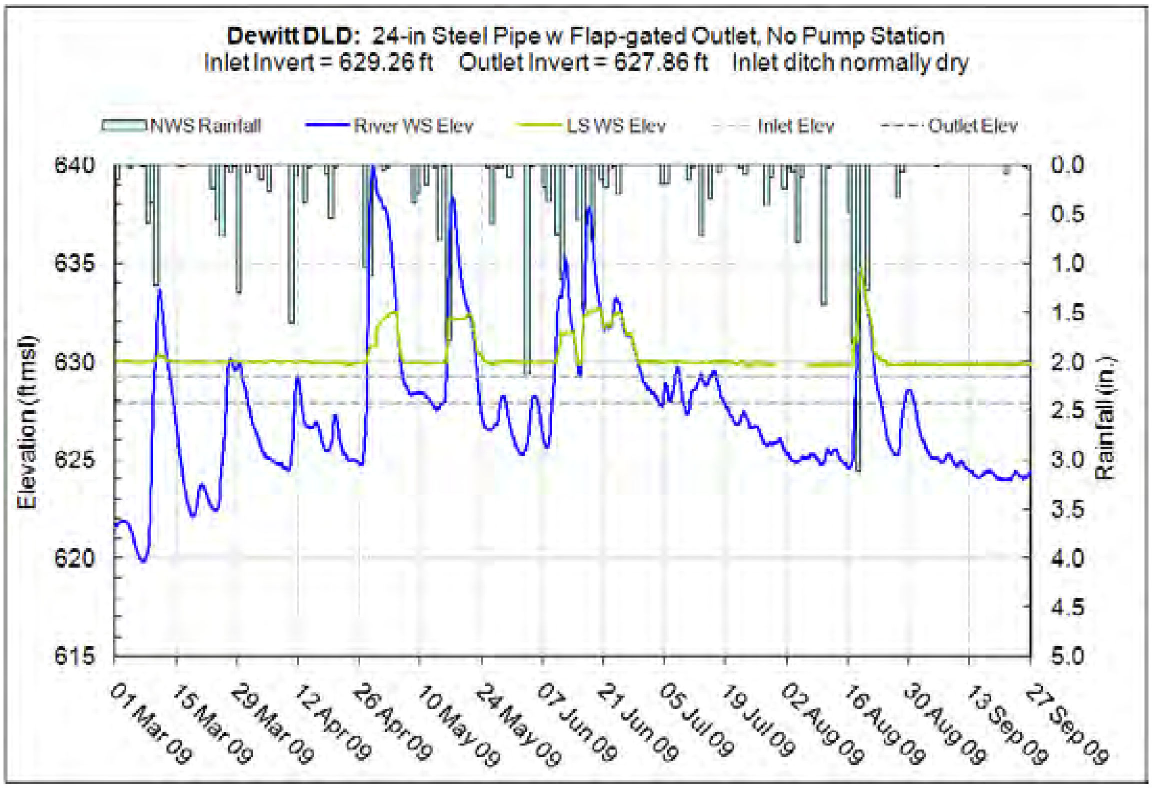

Figure 10.36.5 – Invert elevations, Dewitt DLD

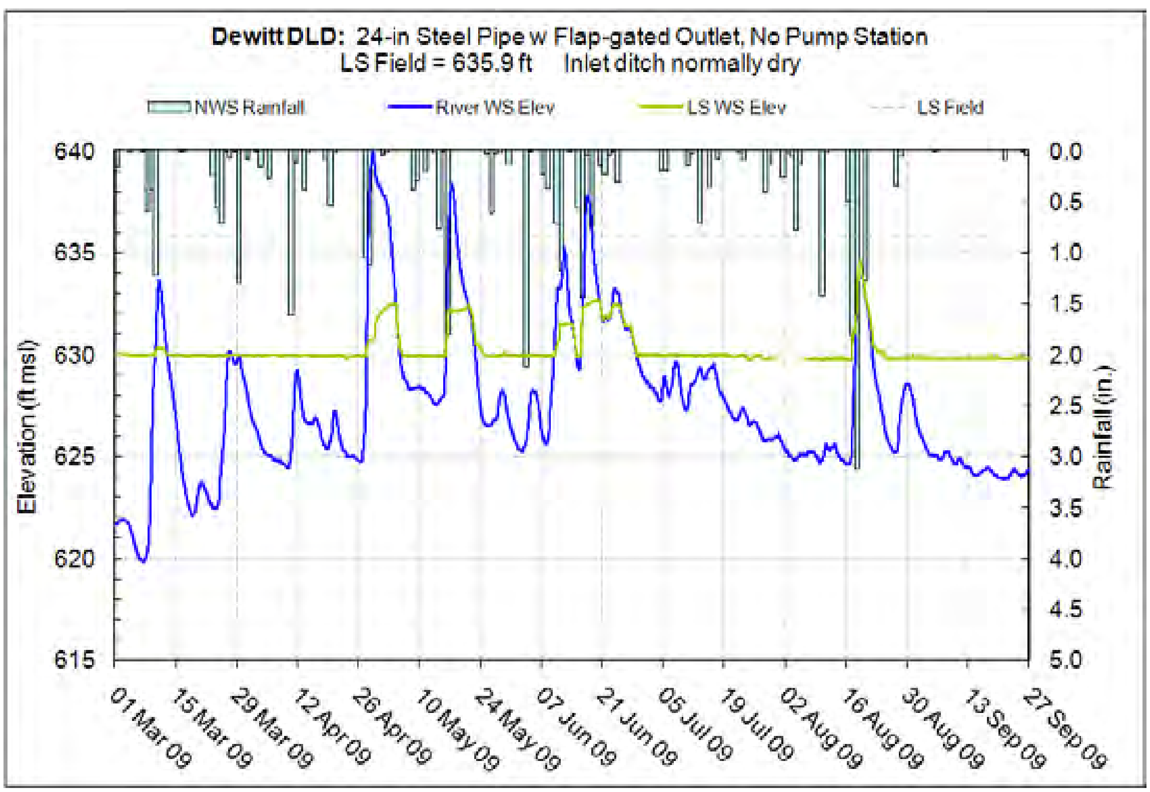

Figure 10.36.6 – Surveyed field elevations, Dewitt DLD

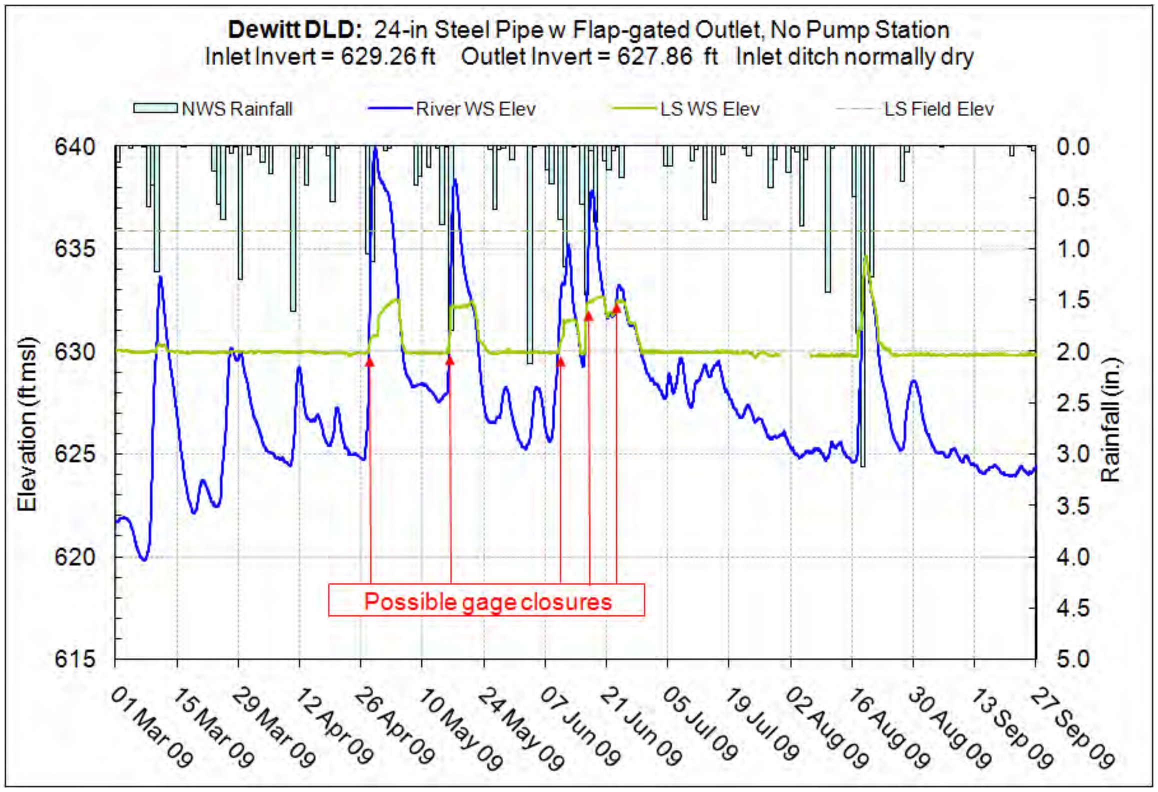

Figure 10.36.7 – NSR socioeconomic impacts, Dewitt DLD

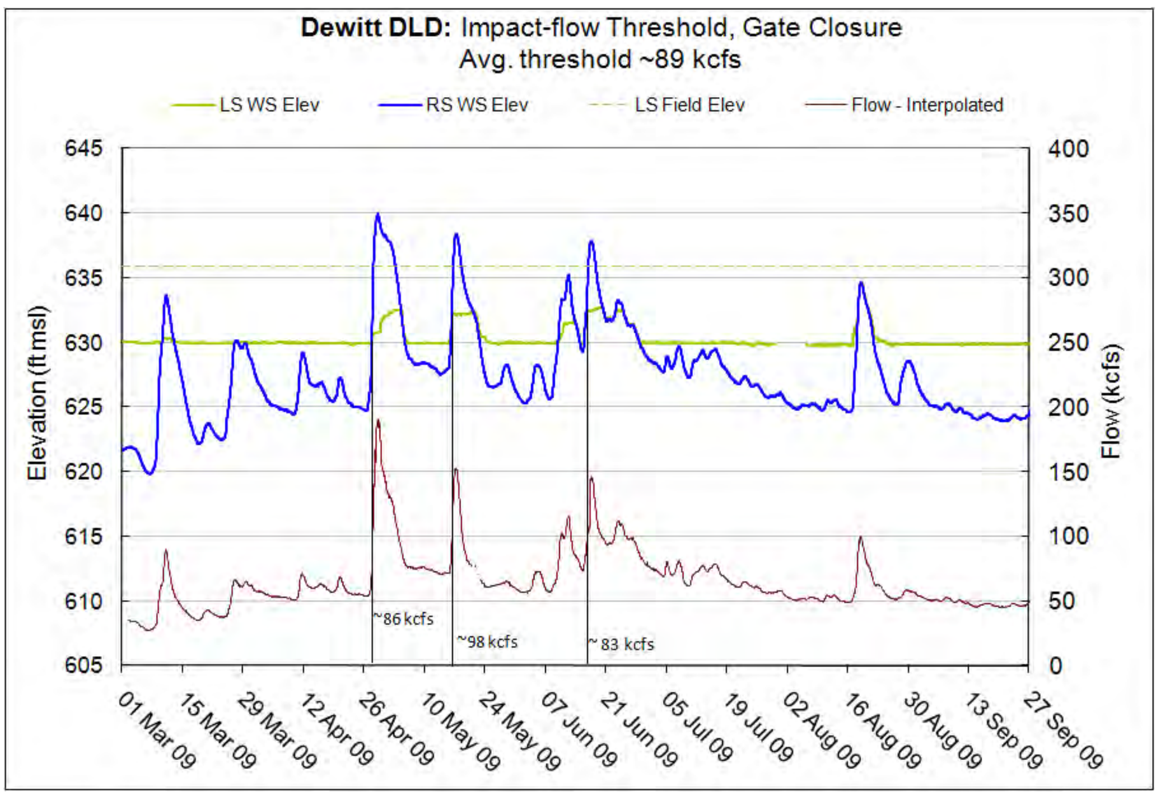

Figure 10.36.8 – Impact-flow threshold (gate closure), Dewitt DLD

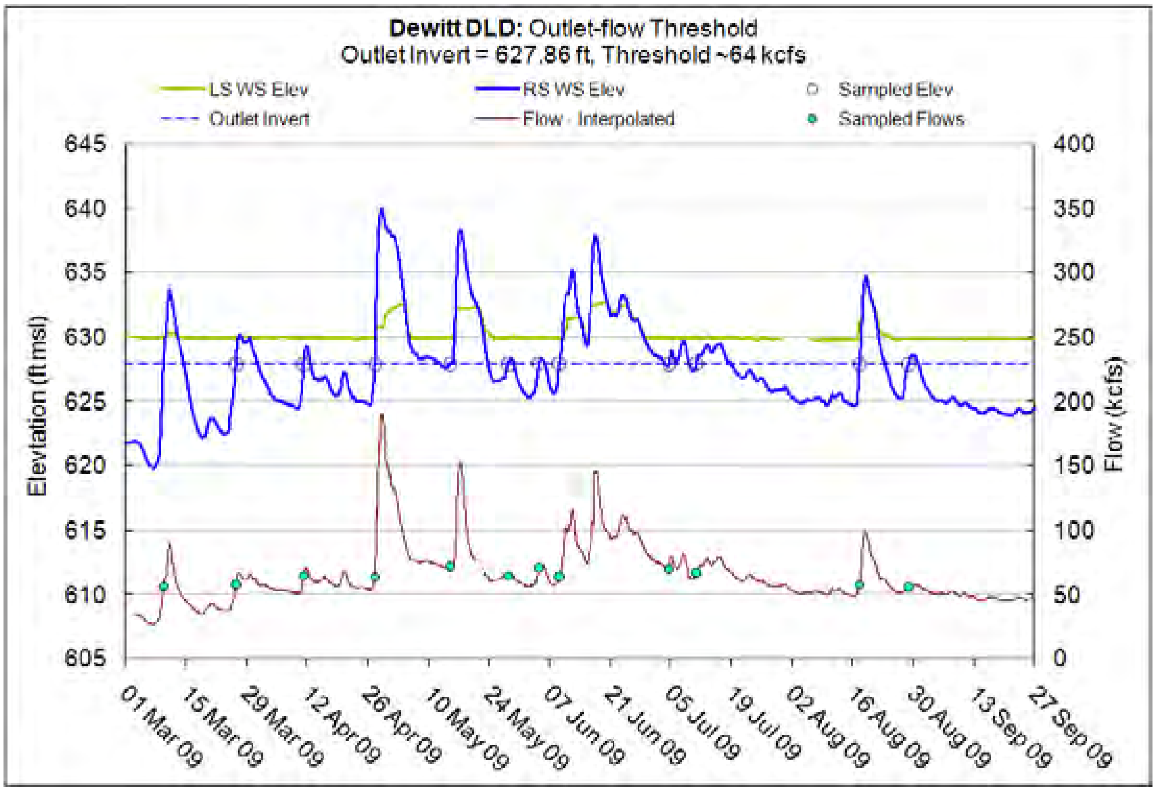

Figure 10.36.9 – Outlet-flow threshold, Dewitt DLD

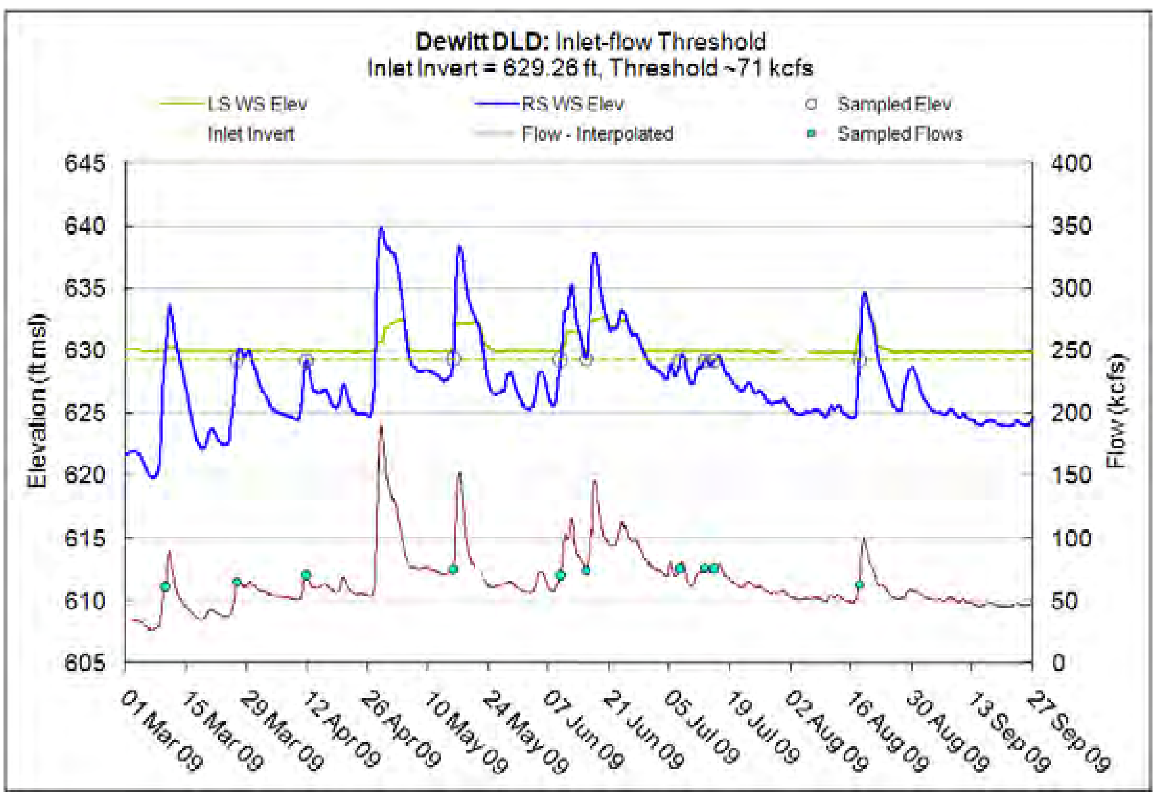

Figure 10.36.10 – Inlet-flow threshold, Dewitt DLD

10.37 Miami LD No. 1

The Miami LD No. 1 supplemental site is located at RM 252.1 in the Brunswick Bend on the north bank of the Missouri River in Carroll County, MO (Figure 10.37.1). The site is 1.8 RM upstream of the Brunswick LD site and 2.1 RM upstream of the confluence of the Grand River with the Missouri River. The drainage structure at this site is a single 48-in. CMP through the main levee with an open inlet and a flap-gated outlet. The invert elevation of the inlet is 627.11 ft and the invert elevation of the outlet is 627.02 ft, meaning the culvert has an adverse slope. The excavated interior drainage ditch has a berm on the right LS bank. The site has no pump and the structure drains directly to the Missouri River.

Two data loggers were installed at the site in 2009. The LS data logger is located at the inlet of the structure in the excavated inlet ditch. The RS data logger was installed 150 ft US of the outlet of the structure on the Missouri River.

Field and berm elevations were surveyed in 2009. The left bank field of the ditch has a typical elevation of 633.37 ft. This field is not protected by a berm. The field on the right bank of the ditch has a typical elevation of 636.02 ft. This right-bank field is protected by a berm with a surveyed elevation of 644.42 ft. The unprotected left bank field's elevation (633.37 ft) was used in the analysis. Flows were estimated at the site by lagging the flow record of USGS Waverly to the site.

Results and Discussion

- Table 10.37.1 summarizes the results for the May 2009 created spring rise, and the Missouri River flows estimated to reach the outlet and inlet of the site's drainage structures.
- Table 10.37.2 summarizes the socioeconomic impacts produced by the natural spring rises at the site in May 2009. The site was not monitored in 2008. Gates were closed for period varying between a little over a day to almost 5 days.
- Figure 10.37.3 shows the spring pulse release on May 18 and its arrival time to the site. The created spring pulse could not be identified. Based on the attenuation analysis, the spring pulse accounts for 0 kcfs of the total 62-kcfs Missouri River flow at this river mile, or 0% of the total flow.
- Figure 10.37.4 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site shown.
- Figure 10.37.5 shows the full period of the monitoring record with the inlet and outlet elevations of the drainage structure.
- Figure 10.37.6 shows the 2009 surveyed field elevation for the LS field.
- Figure 10.37.7 combines the information gained on the outlet inverts and the field elevations to separate out possible socioeconomic impacts produced by natural spring rises during the monitoring record. Gate closure was the identified impact.
- Figure 10.37.8 shows the estimation of the flows in the Missouri River that resulted in gate closures. The elevation at which gates closed was variable as were the flows that triggered the closures. The average gate-closure threshold flow was 82 kcfs.
- Figure 10.37.9 estimates outlet-flow threshold. The flow in the Missouri River required to reach the outlet invert of the drainage structure was 66 kcfs.
- Figure 10.37.10 shows the estimation of the inlet-flow threshold. Based on the 2009 survey of the site, the culvert at the Miami LD 1 site is adverse in slope with its inlet

(627.02 ft) at a lower elevation than its outlet (627.11 ft). For this reason, the inlet and outlet threshold flows for this site were assumed to be the same (66 kcfs).

Conclusions

No socioeconomic impacts due to the created spring pulse from Gavins Point Dam were observed. Based on the attenuation analysis, the spring pulse accounts for 0 kcfs of the total 62-kcfs Missouri-River flow at this river mile, or 0% of the total flow. Socioeconomic impacts at the site appear to be gate closures. Flow thresholds for gate closures and inlet and outlet inverts were estimated although the drainage site does not empty directly into the Missouri River. The estimate was done because the stages recorded in the main stem and at the landside of the site appear to have some correlation.

Figure 10.37.1 – Miami LD No. 1 location

Figure 10.37.2 – Miami LD No. 1 site and gages. Landside data logger and inlet culvert (top left). Outlet of 48-in. culvert looking upstream toward river data logger (top right). Inlet ditch and fields (bottom left). River data logger (bottom right).

Table 10.37.1 – Miami LD No. 1 results

Spring Pulse from Gavins Point Dam	*May-09*	*Mar-08*
Created spring rise, ft	0	-
Estimated created spring rise flow, kcfs	0.2	-
Estimated MR flow at site, kcfs	62	-
% of MR flow	0.4	-

Outlet-flow Threshold	*May-09*	*Mar-08*
Elev, ft	627.11	-
Estimated MR flow at site, kcfs	66	-

Inlet-flow threshold	*May-09*	*Mar-08*
Elev, ft	627.11	-
Estimated MR flow at site, kcfs	66	-

Table 10.37.2 – Miami LD No. 1 NSR socioeconomic impacts

2009 Natural Spring Rise Impacts	*LS Flooding*	*RS Flooding*	*Gate Closure*
Elev, ft	no flooding	no flooding	-
Impact duration, dy	-	-	1.3 – 4.9
Estimated MR flow at site, kcfs	-	-	82

2008 Natural Spring Rise Impacts

Not monitored in 2008.

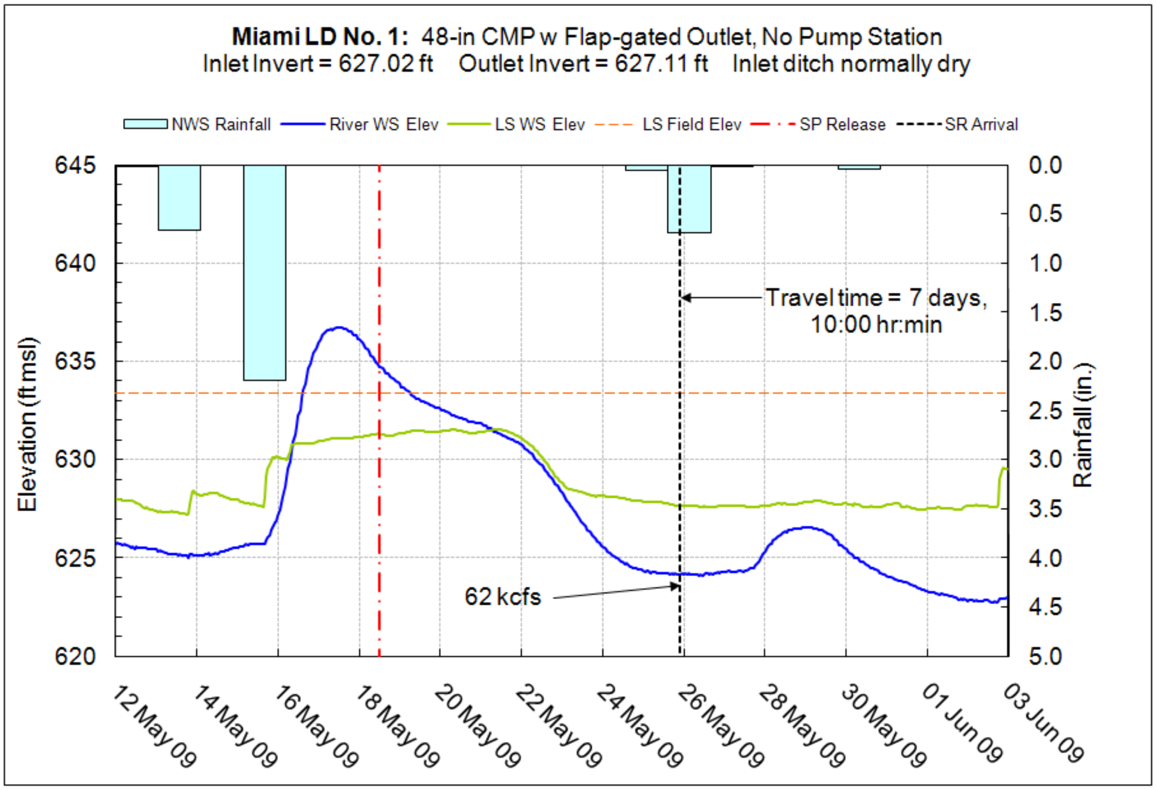

Figure 10.37.3 – Spring rise at Miami LD No. 1

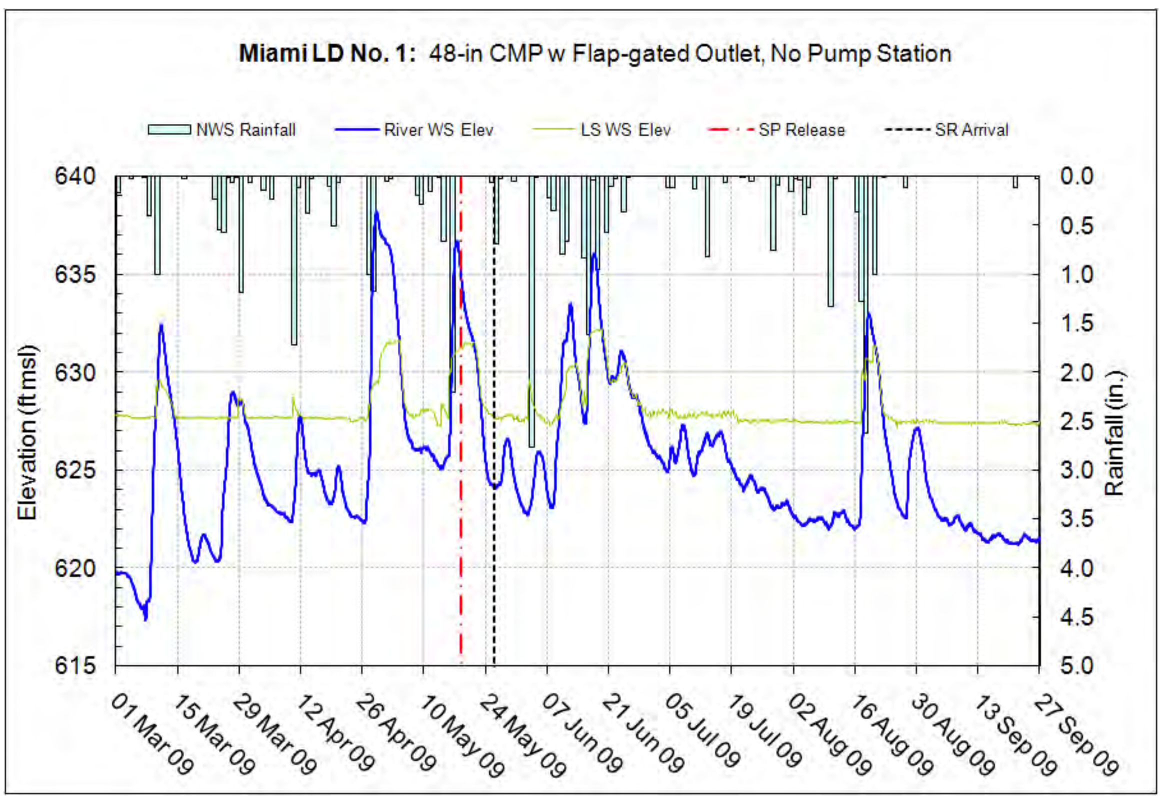

Figure 10.37.4 – Full monitoring record, Miami LD No. 1

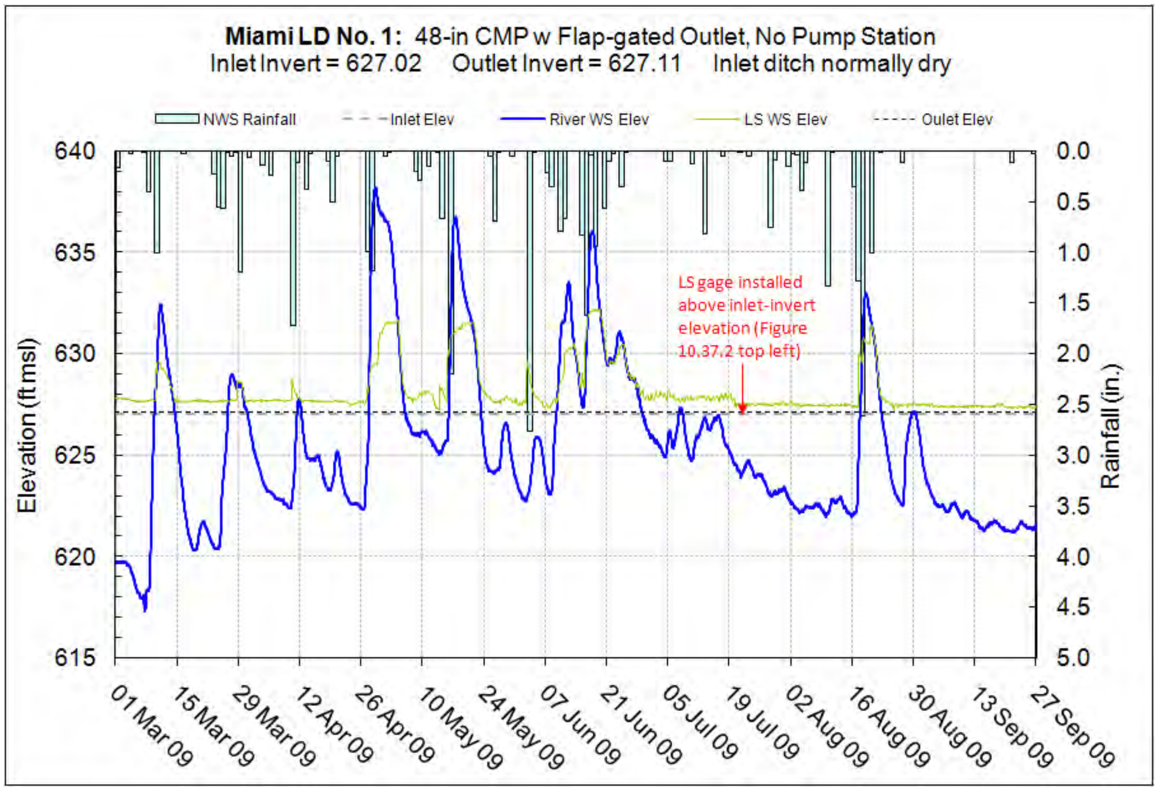

Figure 10.37.5 – Invert elevations, Miami LD No. 1

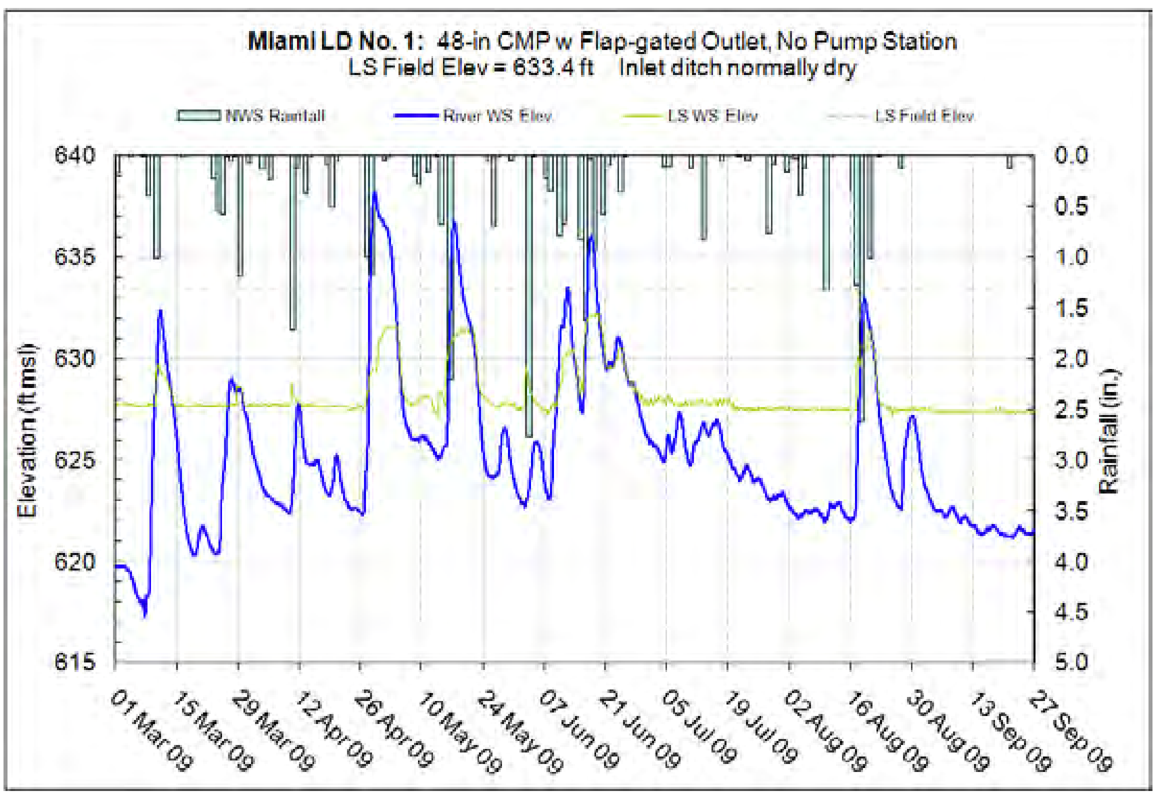

Figure 10.37.6 – Surveyed field elevations, Miami LD No. 1

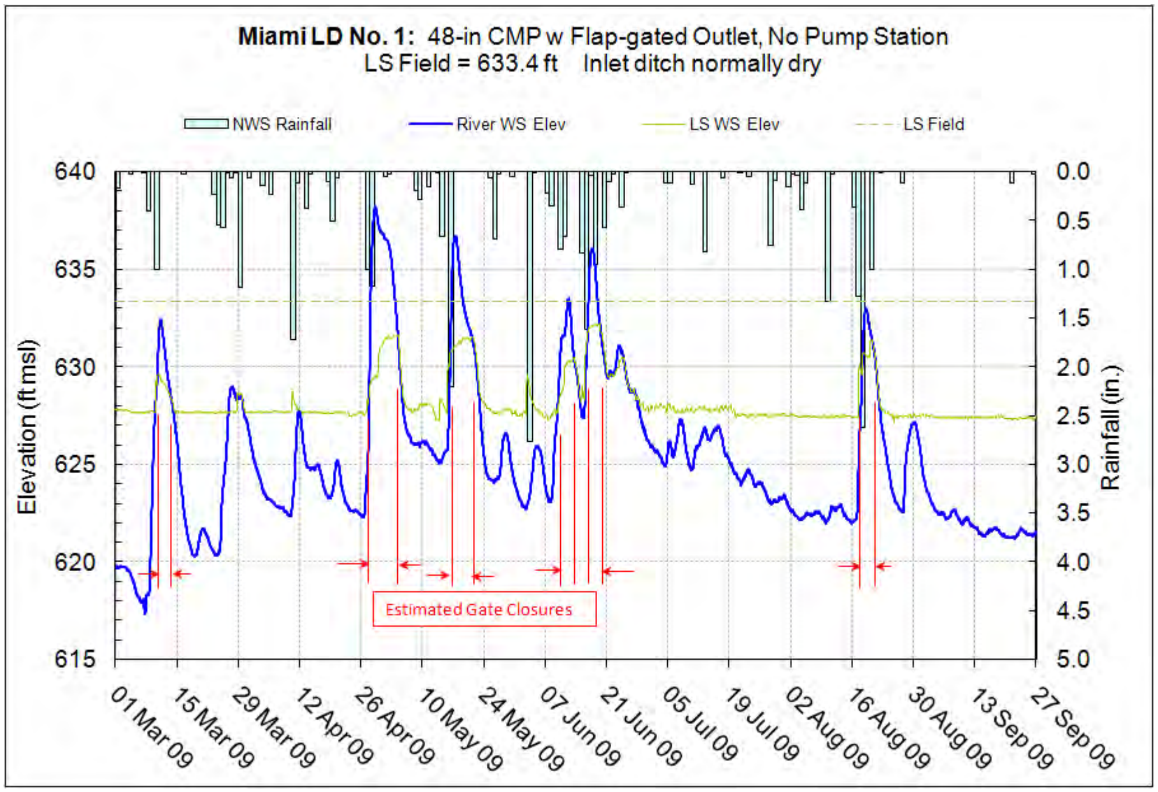

Figure 10.37.7 – NSR socioeconomic impacts, Miami LD No. 1

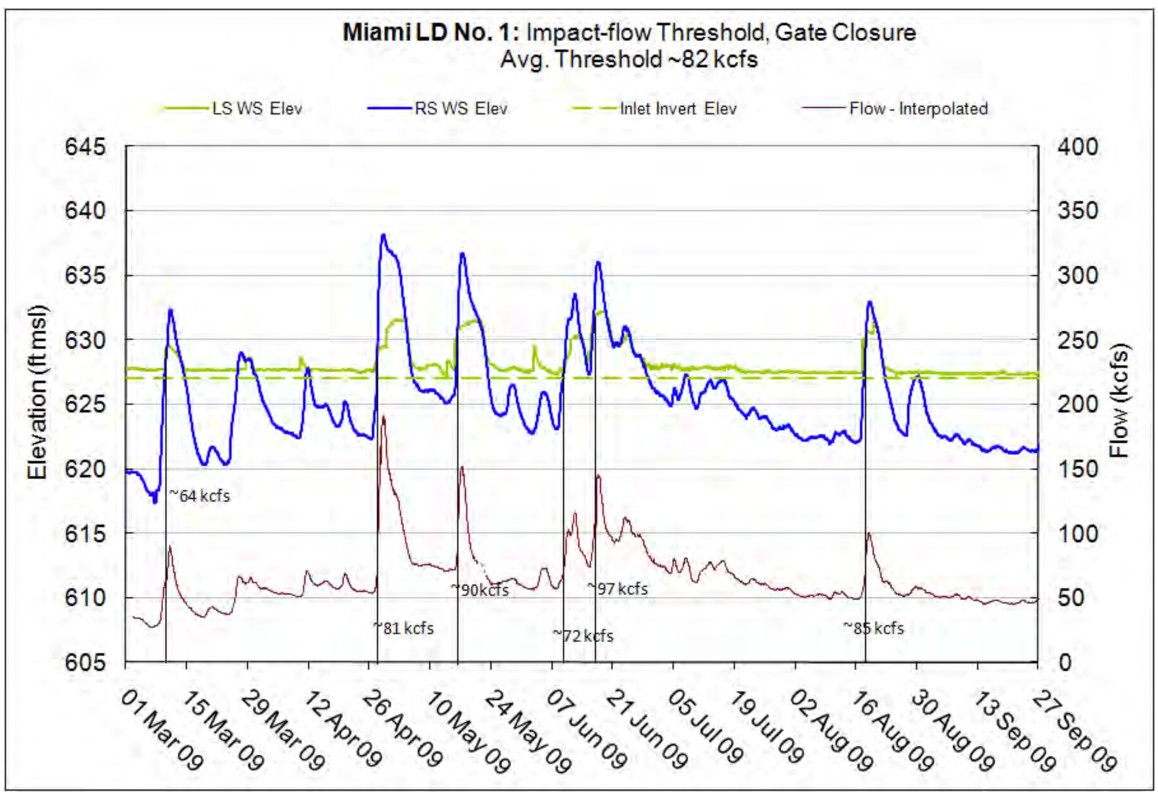

Figure 10.37.8 – NSR impact-flow threshold (gate-closure), Miami LD No. 1

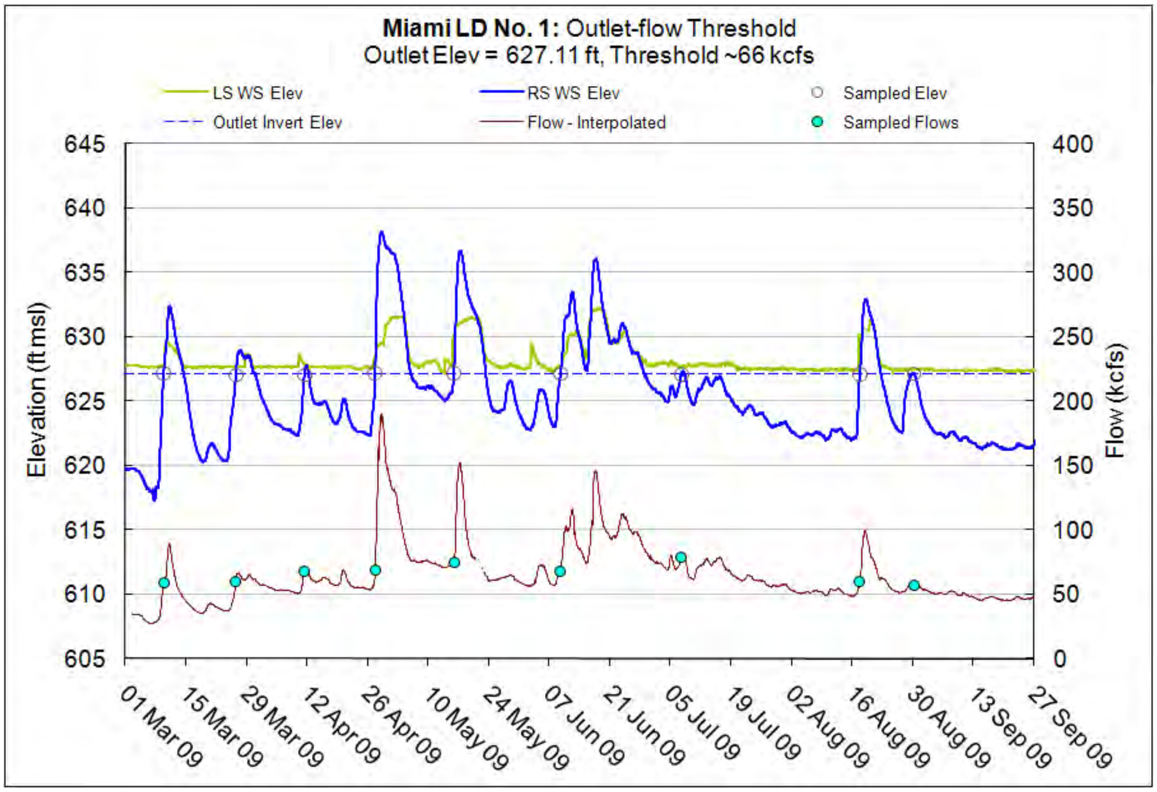

Figure 10.37.9 – Outlet-flow threshold, Miami LD No. 1

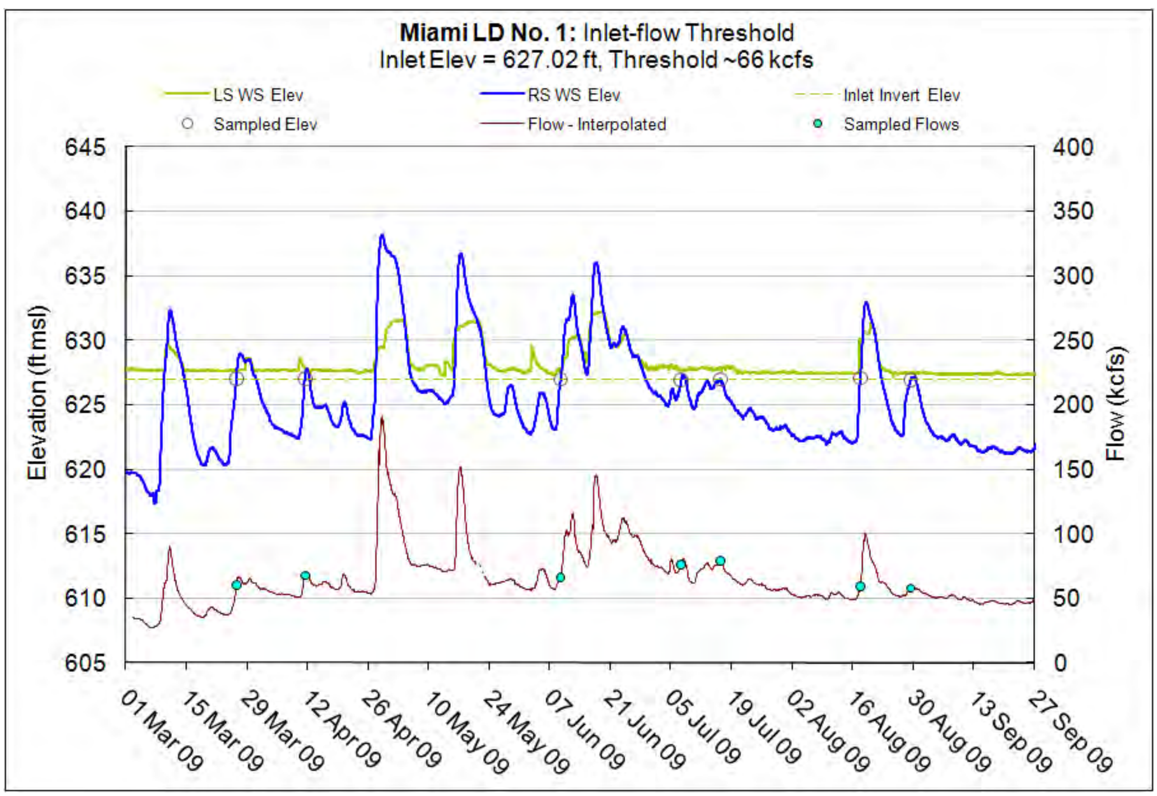

Figure 10.37.10 – Inlet-flow threshold, Miami LD No. 1

10.38 Brunswick LD

The Brunswick LD supplemental site is located along the Grand River just upstream of the Grand River confluence with the Missouri River in Chariton County, MO (Figure 10.38.1). The river mile of the Grand and Missouri River confluence is RM 249.9, however, the approximate Missouri River location of the site is RM 250.3. The site's outlet empties into an approximately 600-ft drainage ditch that flows into the Grand River about 1,900 ft upstream of the confluence. The slope of the Grand River from the drainage ditch outlet to the Missouri River confluence is negligible. The drainage structure at this site is a single 60-in. CMP culvert through the main levee with an open inlet and a flap-gated outlet (Figure 10.38.2). The inlet ditch is excavated slightly below the field elevation and there are no berms on either side of the inlet ditch. The site has a pump station with a 24-in. inlet pipe. The outlet of the pump station pipe is encased in a scrap section of 60-in. CMP. The inlet invert of the 60-in. CMP culvert is 623.42 ft and the outlet invert is 622.27 ft. The elevation of the top of the levee at the drainage structure is 643.65 ft.

Two data loggers were installed (Figure 10.38.3). The LS data logger was installed in the inlet ditch about 100 ft upstream of the culvert inlet in ponded water. The RS data logger was installed on the right bank of the Grand River about 100 ft downstream of the confluence of the drainage ditch and the Grand River.

Field elevations were surveyed in 2009. The typical field elevation within the levee is 629.1 ft. This elevation was surveyed about 200 ft inside the levee and west of the inlet drainage ditch. All elevations are in the NAVD 88 datum. Flows in the Missouri River at the river mile of the site were estimated by lagging the flow record of USGS Waverly to the site. Flow thresholds were not estimated because the site drains to the Grand River 1,900 feet upstream of the Missouri River.

Results

§ Table 10.38.1 summarizes the results for the May 2009 created spring rise, and the Missouri River flows estimated to reach the outlet and inlet of the site's drainage structure.

§ Table 10.38.2 summarizes the socioeconomic impacts produced by the natural spring rises in May 2009. This site was not monitored in 2008. Pumping occurred for almost 4 days and gate closures ranged from 3.6 to 10 days.

§ Figure 10.38.4 shows the spring pulse release on May 18 and its travel time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise created by the May spring pulse was not identifiable. Based on the attenuation analysis, the spring pulse accounts for 0 kcfs of the total 62-kcfs Missouri-River flow at this river mile, or 0% of the total flow.

§ Figure 10.38.5 shows the full period of the monitoring record with the time of the May spring pulse's release and its arrival time at the site shown.

§ Figure 10.38.6 shows the full period of the monitoring record with the inlet and outlet invert elevation of the drainage structure.

§ Figure 10.38.7 shows the 2009 surveyed field elevations for the RS and LS fields.

§ Figure 10.38.8 shows the possible impacts during the 2009 monitoring period.

§ Figure 10.38.9 show the estimation of the impact flow-threshold for pumping. Pumping might have occurred when flow reached around 88 kcfs on the Missouri River at the site.

- § Figure 10.38.10 shows the estimation of the impact flow-threshold for gate closures. Three of the most distinct closures were sampled to estimate the gate-closure threshold. If all the points had been used, the gate-closure threshold would have been 60 kcfs which is also the outlet-flow threshold. The 60-kcfs result does not make sense because water would need to be above the outlet invert to create gate closure. This is why only the three most distinct points were used. Gates appear to have closed when Missouri River flows reached 67 kcfs.
- § Figure 10.38.11 shows the estimation of the outlet-flow threshold. Flows in the Missouri River required to reach the outlet-invert elevation are 60 kcfs.
- § Figure 10.38.12 shows the estimation of the inlet-flow threshold. Flow in the Missouri River required to reach the inlet invert elevation are 61 kcfs.

Conclusions

No socioeconomic impacts were created by the spring pulse during the 2009 monitoring period at this site. Natural spring rises produced pumping and gate closures. Based on the attenuation analysis, the spring pulse accounts for 0 kcfs of the total 62-kcfs Missouri-River flow at this river mile, or 0% of the total flow.

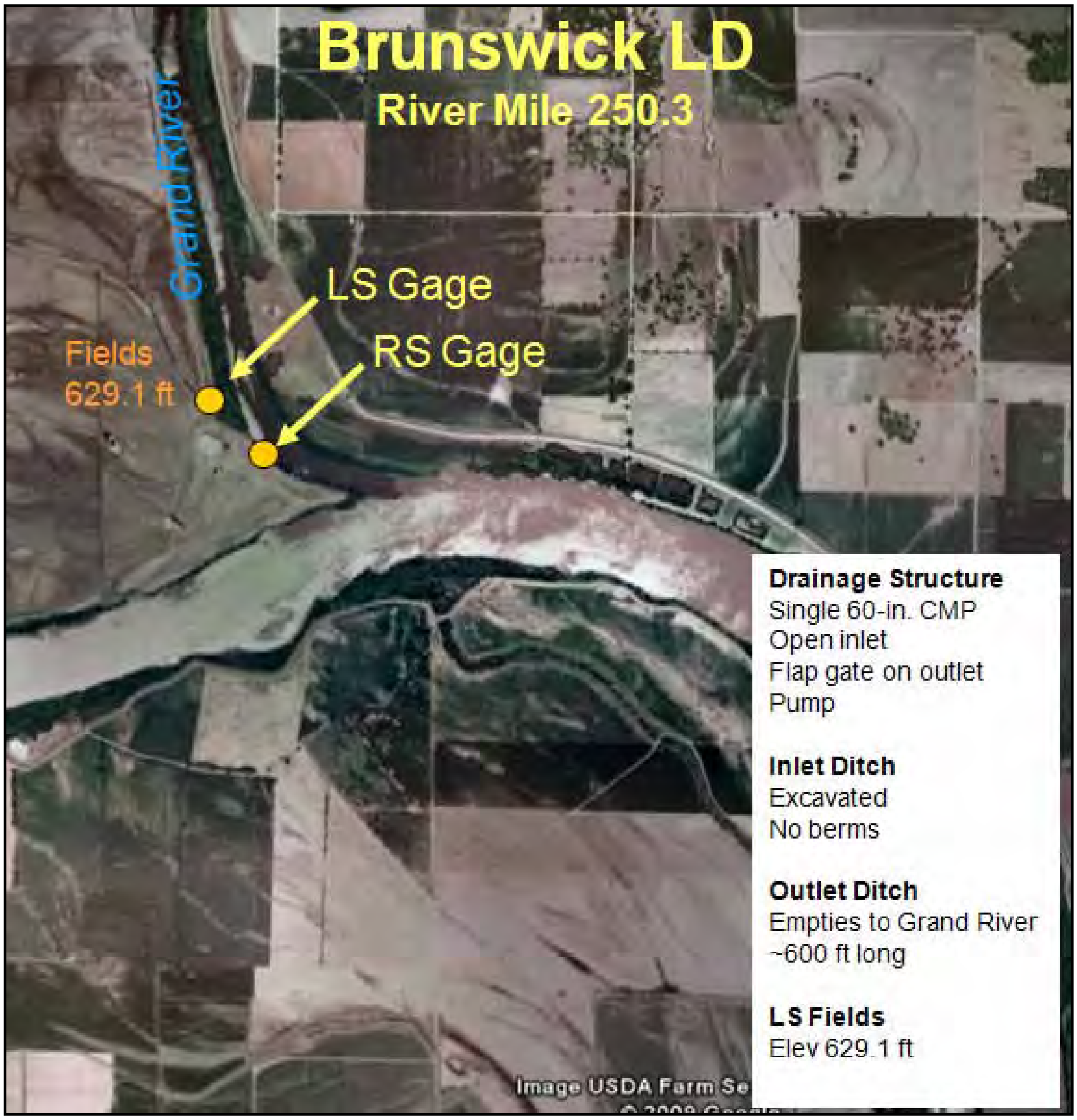

Figure 10.38.1 – Brunswick LD location

Figure 10.38.2 – Brunswick LD site. Landside 60-in. culvert inlet through main levee (top left). Riverside flap-gated outlet with pump station outlet pipe to left; flap gage controlled by pulley (top right). Top of levee looking landward at inlet ditch and pump station with engine (center left). Outlet ditch to mouth of Grand River (center right). Pump station with 24-in. inlet pipe (bottom left). Pump station outlet encased in section of scrap 60-in. CMP (bottom right).

 

Figure 10.38.3 – Brunswick LD gages. LS data logger on inlet ditch (left). Data logger on Grand River bank; end of pipe covered with silt by August 2009 (right).

Table 10.38.1 – Brunswick LD results

Spring Pulse from Gavins Point Dam		
	May-09	***Mar-08***
Created spring rise, ft	n.a.	-
Estimated created spring rise flow, kcfs	0	-
Estimated MR flow at site, kcfs	62	-
% of MR flow	0	-
Outlet Flow Threshold		
	May-09	***Mar-08***
Elev, ft	622.27	-
Estimated MR flow at site, kcfs	60	-
Inlet-flow threshold		
	May-09	***Mar-08***
Elev, ft	623.4	-
Estimated MR flow at site, kcfs	61	-

Table 10.38.2 – Brunswick LD NSR socioeconomic impacts

2009 Natural Spring Rise Impacts

	LS Flooding	*Pumping*	*Gate Closure*
Elev, ft	629.1	-	-
Impact duration, dy	No flooding	3.7	3.6 – 10.0
Estimated MR flow at site, kcfs	-	88	67

2008 Natural Spring Rise Impacts

Not monitored in 2008.

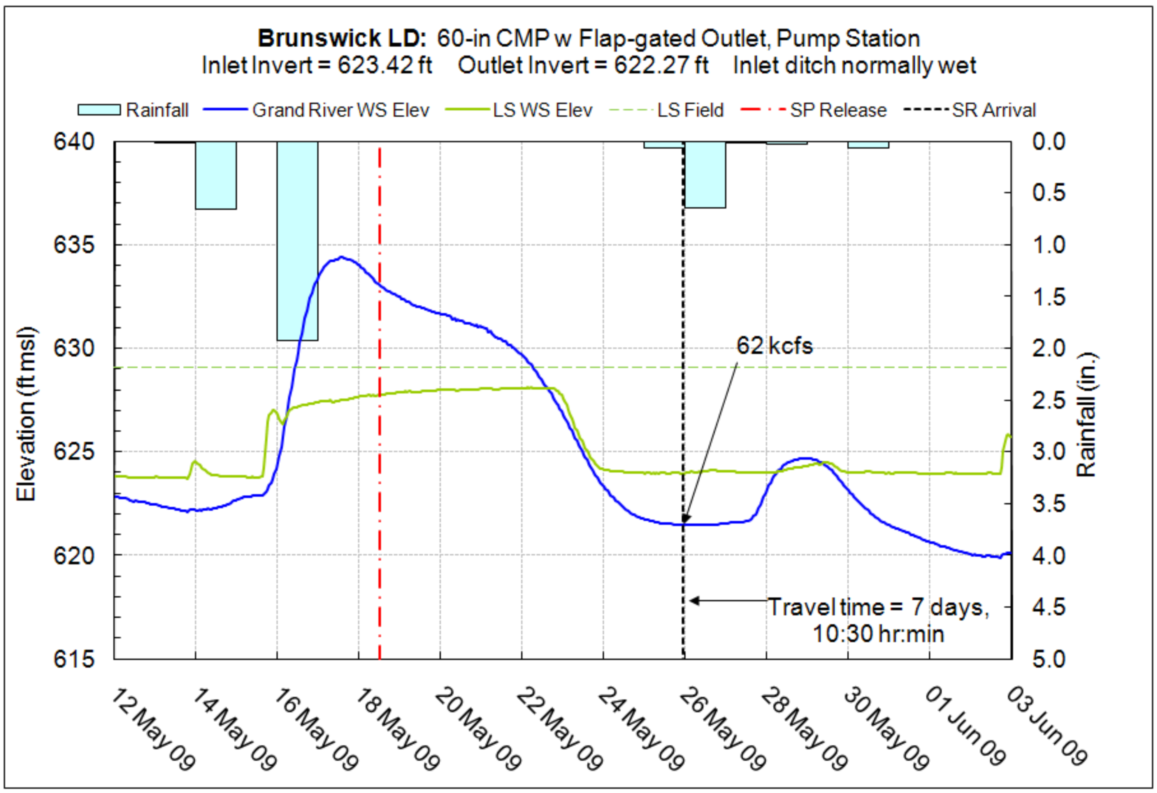

Figure 10.38.4 – Spring rise at Brunswick LD

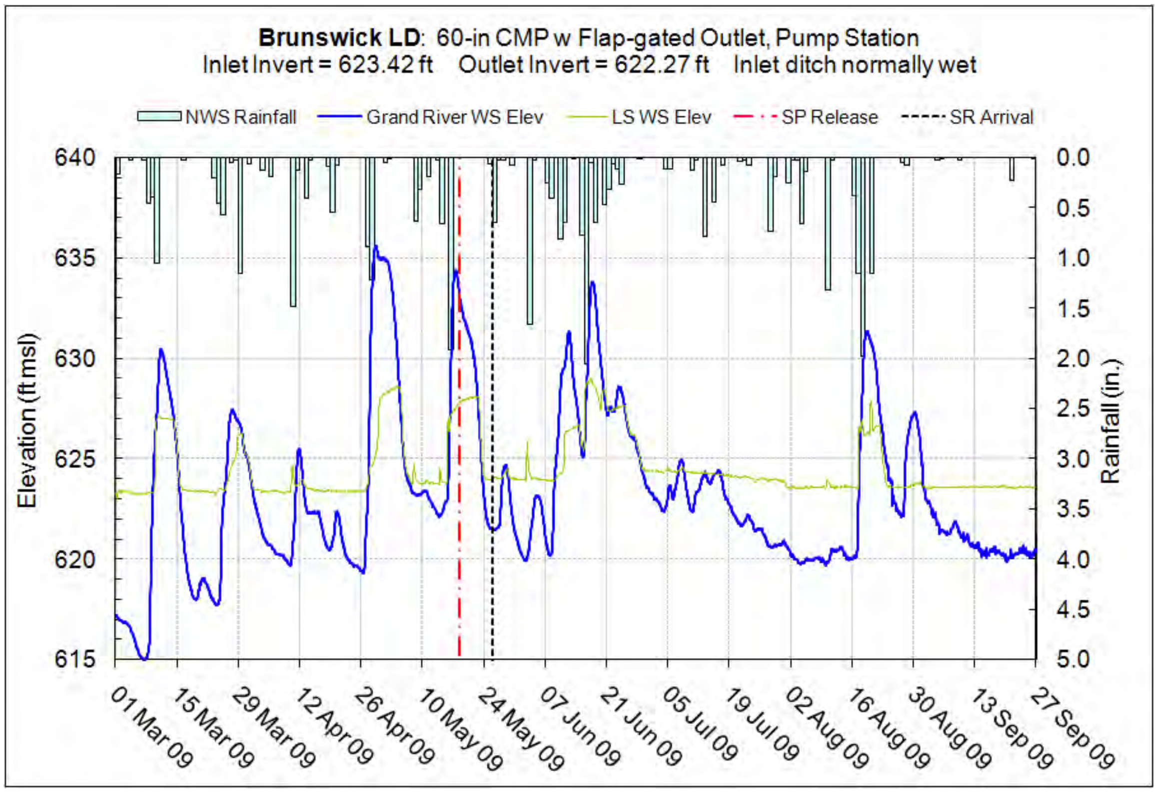

Figure 10.38.5 – Full monitoring record at Brunswick LD

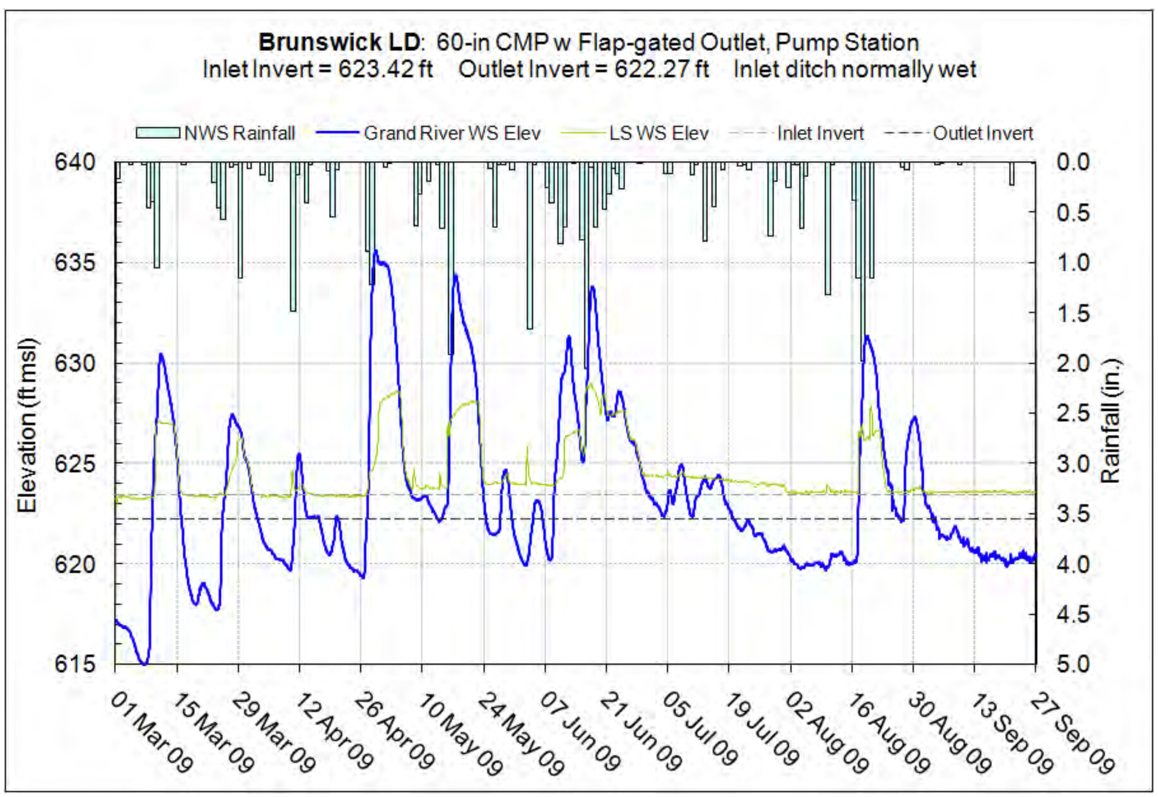

Figure 10.38.6 – Invert elevations, Brunswick LD

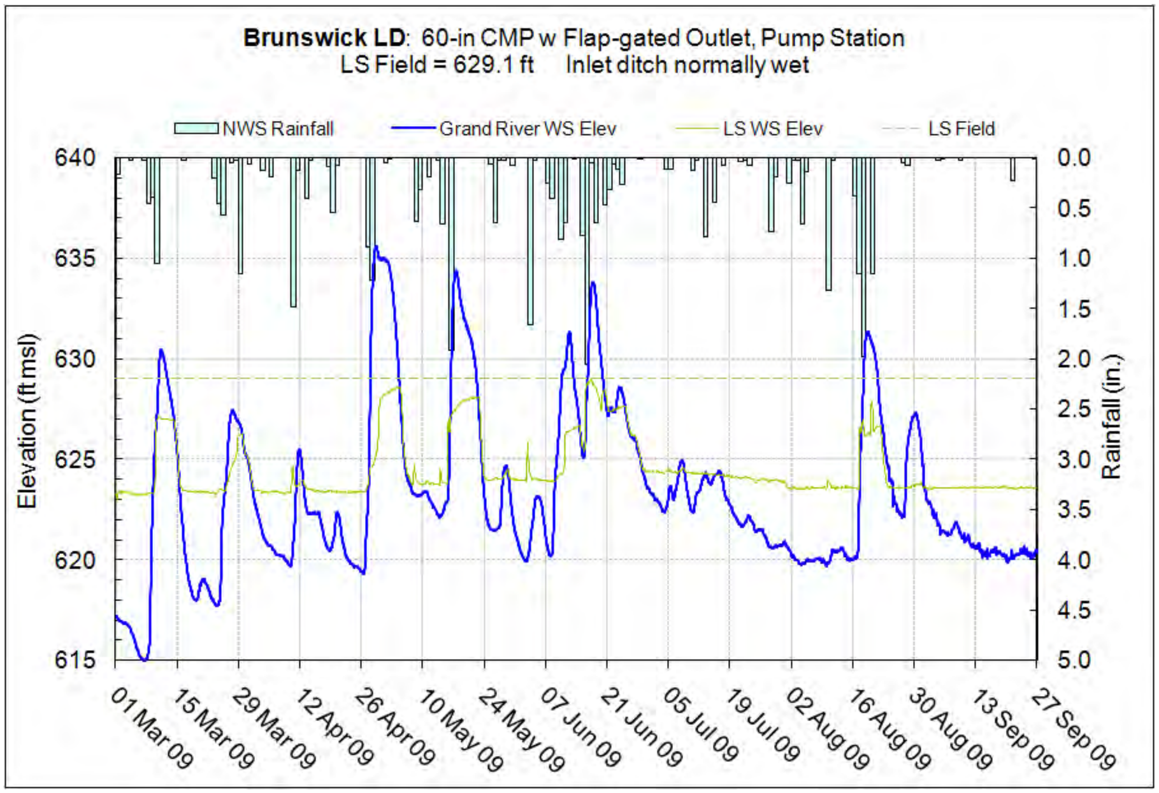

Figure 10.38.7 – Surveyed field elevations, Brunswick LD

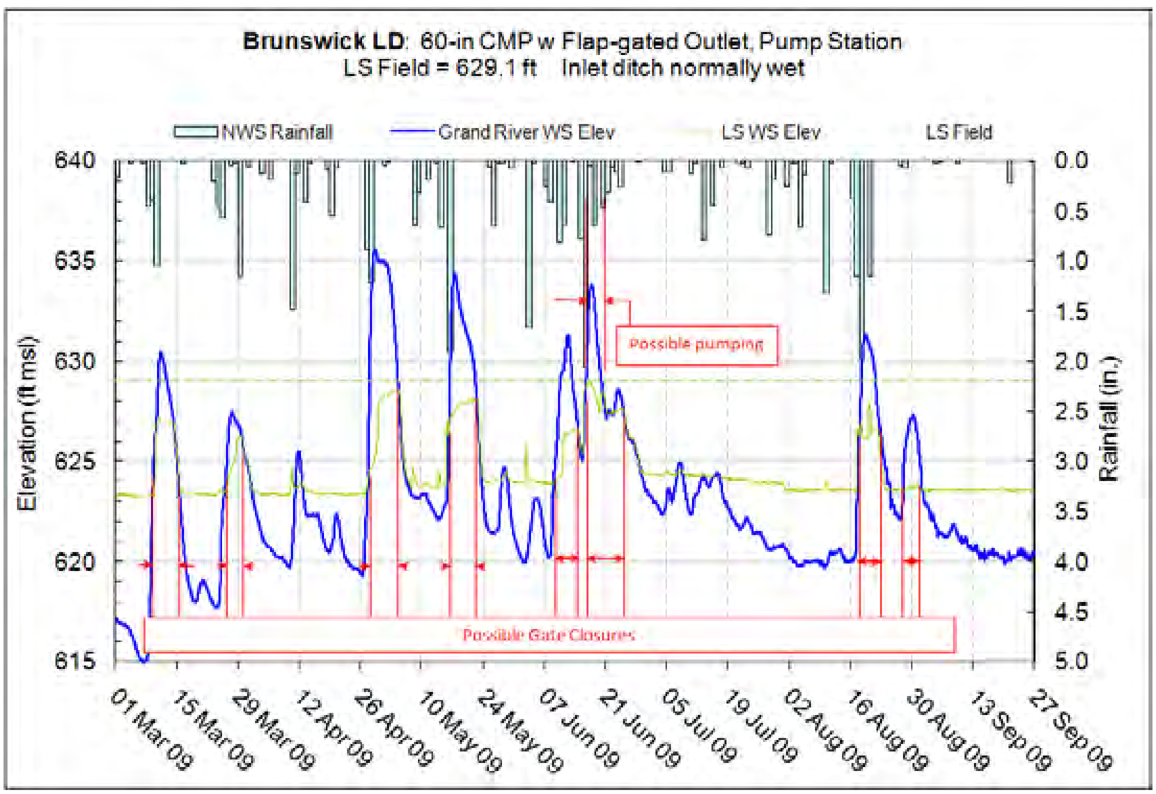

Figure 10.38.8 – NSR socioeconomic impacts, Brunswick LD

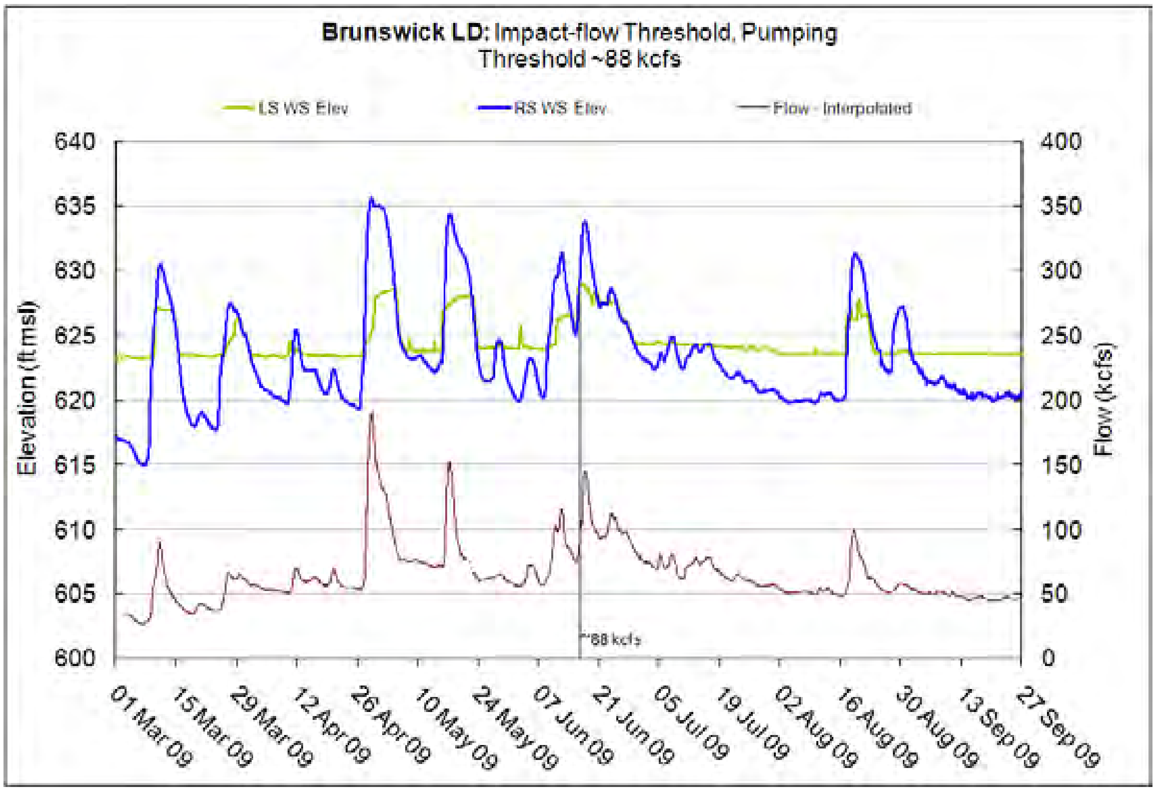

Figure 10.38.9 – Impact-flow threshold (pumping), Brunswick LD

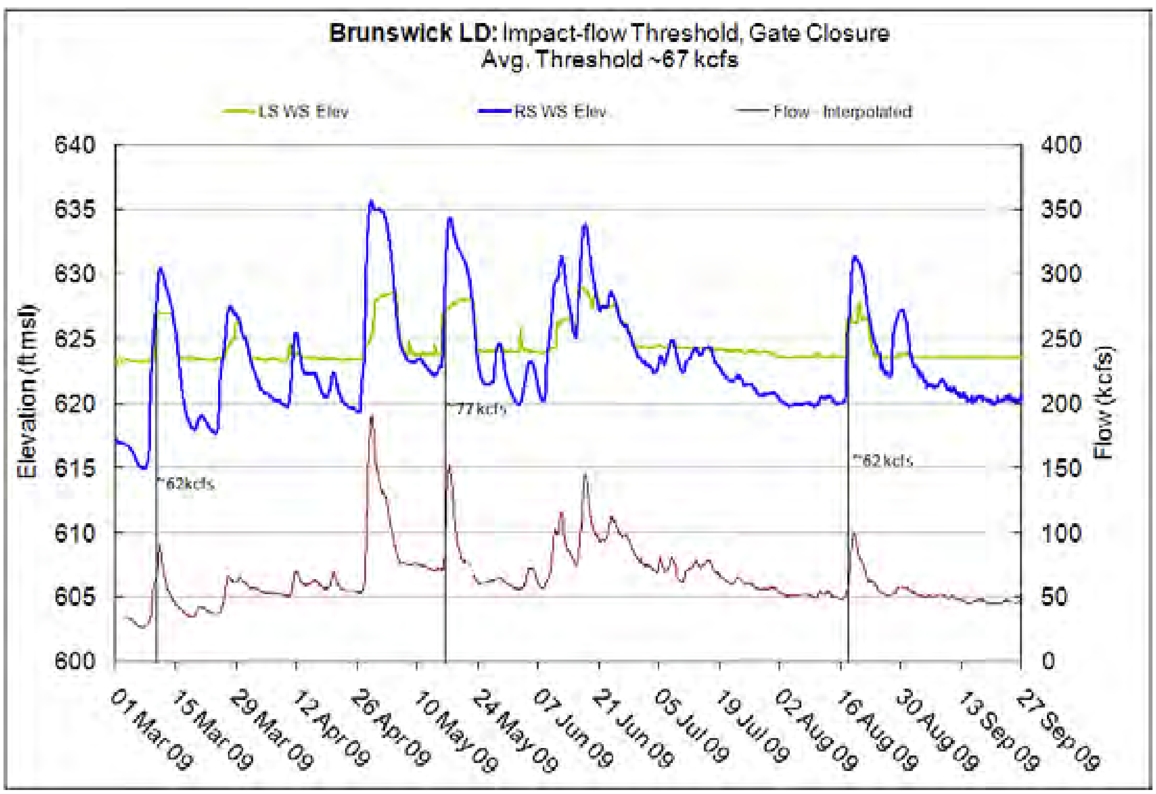

Figure 10.38.10 – Impact-flow threshold (gate closure), Brunswick LD

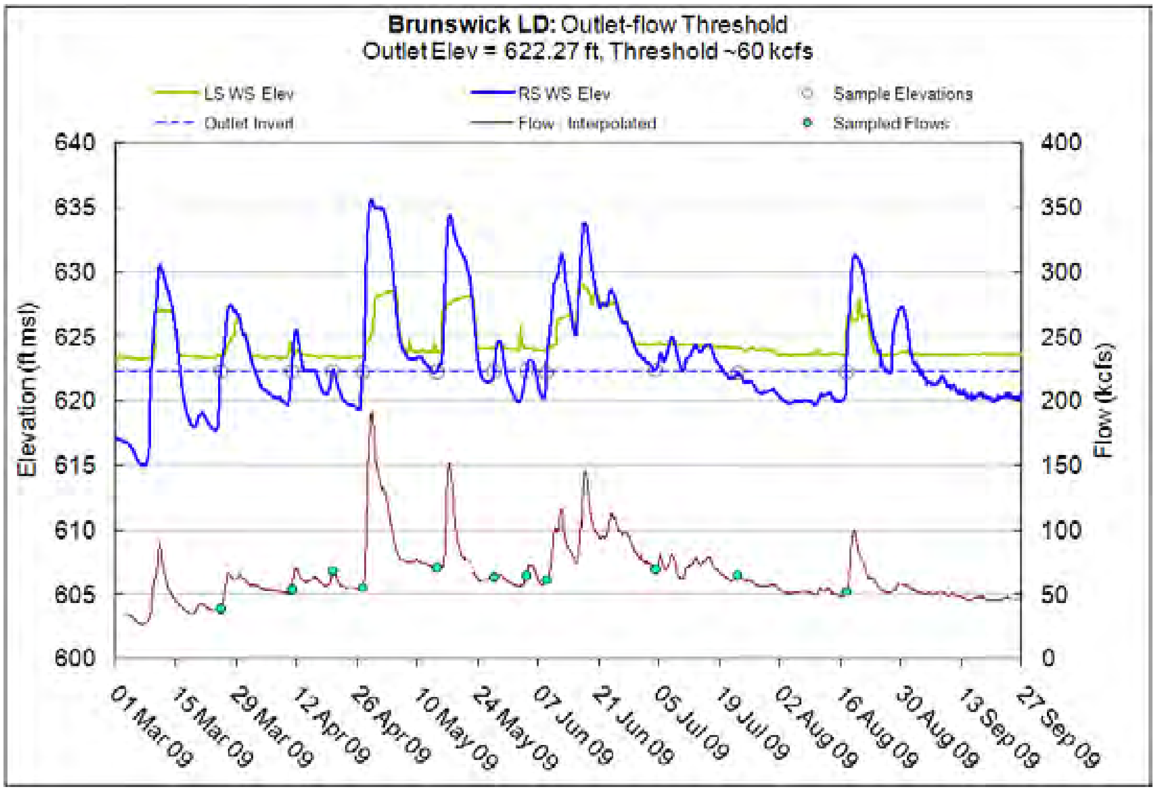

Figure 10.38.11 – Outlet-flow threshold, Brunswick LD

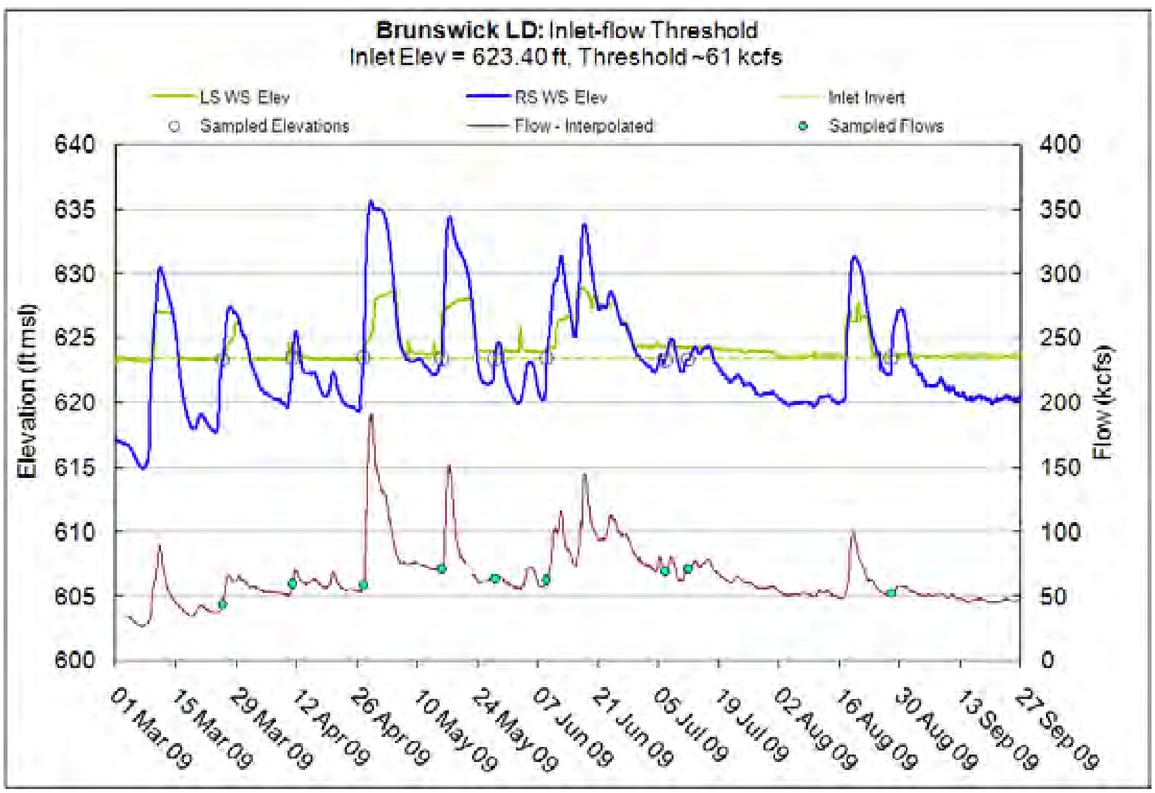

Figure 10.38.12 – Inlet-flow threshold, Brunswick LD

10.39 L-246 Palmer Creek

The L-246 Palmer Creek supplemental site is located at RM 241.8 on the north bank of the Bushwacker Bend of the Missouri River in Chariton County, MO (Figure 10.39.1). The drainage structure through the main levee at this site is a concrete box culvert with two 5 ft x 5 ft culverts flanking a larger 5 ft x 10 ft culvert through the main levee (Figure 10.39.2). The culverts have slide gates in the gatewell near the centerline of the levee and flap gates on their outlets. The inlet invert elevation of the middle box culvert is 611.55 ft and the inlet inverts of the flanking smaller box culverts are 616.5 ft. The outlet invert elevation of the main culvert is 610.24 ft and the outlet inverts of the flanking culverts are 615.24 ft. The inlets of the structure are open and the inlet ditch is Palmer Creek.

The main culvert of the L-246 Palmer Creek site was monitored in 2008 on the RS and LS. The LS data logger was installed on Palmer Creek just downstream of where the side ditch empties into Palmer Creek. The RS data logger was installed on the side wall of the main levee box culvert outlet. A third data logger was added to this site in 2009 to monitor water level elevations on the LS of a side ditch through a tieback levee (Figure 10.39.3). The drainage structure of the side ditch is a 36-in. CMP with an open inlet and a flap-gated outlet that empties to Palmer Creek (the main ditch). The side ditch drains to Palmer Creek about 300 ft upstream of the structure through the main levee.

Field elevations were surveyed in 2009. The LS of the site is protected by berms along the main channel with a surveyed elevation of 631.0 ft. The tieback berms run along both sides of Palmer Creek from the main levee to far inland past the lake and slope upward. The typical field elevation of the LS field of the site is 625.5 ft. The side ditch through the berm protecting the main ditch has a field elevation of 627.0 ft. Historically, these fields have been cultivated but were fallow and overgrown in 2009. Flows were estimated at the site by lagging the flow record of the Grand River at Sumner to the Missouri River, adding it to the lagged flow record of USGS Waverly, and then lagging the resulting record to the site.

Results and Discussion

- Table 10.39.1 summarizes the results for the May 2009 and March 2008 created spring rises, and the Missouri River flows estimated to reach the outlet and inlet of the site's drainage structures.
- Table 10.39.2 summarizes the socioeconomic impacts produced by the natural spring rises at the site in May 2009 and March 2008. Gates were closed for periods varying between 0.1 to 3.6 days in 2009 and between 6.7 to around 40 days in 2008.
- Figure 10.39.5 shows the spring pulse release on May 18 and its travel time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise created by the May spring pulse was indiscernible. Based on the attenuation analysis, the spring pulse accounts for 0 kcfs of the total 66-kcfs Missouri River flow at this river mile, or 0% of the total flow.
- Figure 10.39.6 shows the full monitoring record with the time of the May spring pulse's release and its arrival time at the site.
- Figure 10.39.7 shows the full monitoring record with the inlet and outlet invert elevations of the drainage structure on the main ditch (Palmer Creek) through the main levee. The invert elevations of the flanking culverts were used to determine the inlet- and outlet-flow thresholds at the site.
- Figure 10.39.8 shows the 2009 surveyed LS berm elevation on the main drainage ditch.

- § Figure 10.39.9 shows the inlet and outlet invert elevations of the side ditch through the berm of the main ditch.
- § Figure 10.39.10 shows the elevation of the field elevation of the side ditch.
- § Figure 10.39.11 shows the estimated socioeconomic impacts on the main ditch. Gate closures were the only identified socioeconomic impacts. Gates were closed for a total of 10 days in 2009.
- § Figure 10.39.12 shows the estimated socioeconomic impacts on the side ditch. Higher water surface elevations in the main ditch (Palmer Creek) appear to have affected drainage from the normally dry side ditch but not to the extent to create overbank flooding. Stop-log structure influences were the only identified socioeconomic impacts. Closures totaled 44 days.
- § Figure 10.39.13 shows the estimation of the gate-closure threshold flow for the main ditch. The average flow in the Missouri River that resulted in gate closures was 110 kcfs.
- § Figures 10.39.14 and 10.39.15 show the estimation of the inlet- and outlet-flow thresholds for the main ditch. Flows in the Missouri River required to reach the inlet elevation are 75 kcfs. Flows in the Missouri River required to reach the outlet elevation are 64 kcfs.
- § Figure 10.39.16 shows the estimation of the gate-closure flow threshold for the 2008 record. The average flow that resulted in gate closure was 135 kcfs.
- § Figures 10.39.17 and 10.39.18 show the estimation of the 2008 outlet- and inlet-flow thresholds. The outlet-flow threshold in 2008 was 62 kcfs and the inlet-flow threshold was 69 kcfs.

Conclusions

No socioeconomic impacts were produced by the created spring rise during the 2009 monitoring period. Based on the attenuation analysis, the spring pulse accounts for 0 kcfs of the total 66-kcfs Missouri-River flow at this river mile, or 0% of the total flow. Natural spring rises resulted in gate closures for both 2008 and 2009.

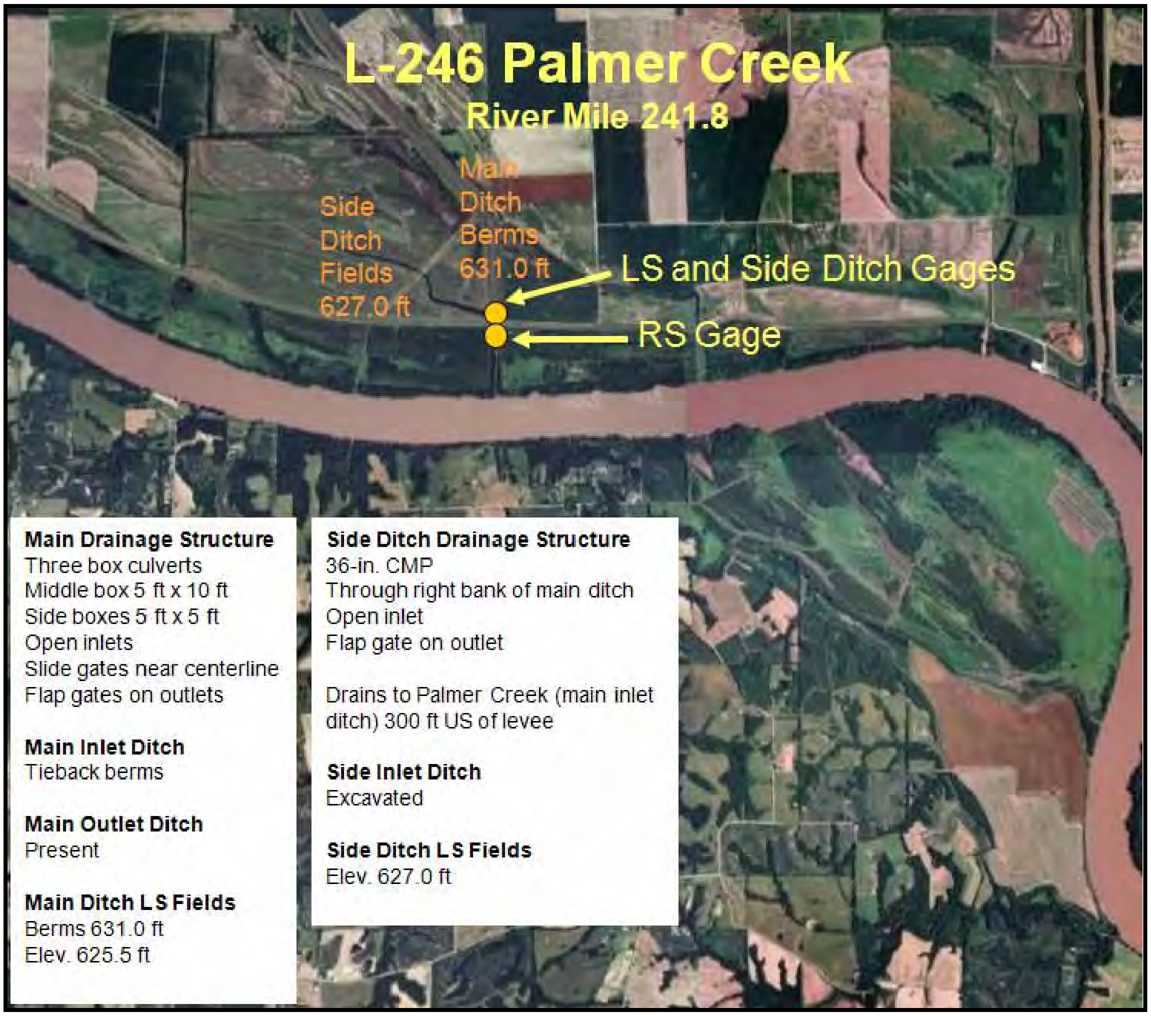

Figure 10.39.1 – L-246 Palmer Creek location

Figure 10.39.2 – L-246 Palmer Creek drainage through main levee. Inlet of box culvert (top left). Outlet of box culvert with flap gates and data logger on left structure wing (top right). Top of levee looking landward at inlet ditch; side ditch culvert on left side; tieback berms on either side of inlet ditch (bottom left). Top of levee looking riverward (bottom right).

Figure 10.39.3 – L-246 Palmer Creek tieback berms. 2006 view looking US along side ditch from crest of Palmer Creek tieback berm (left). 2009 view looking US from crest of main levee across US berm along Palmer Creek to side ditch (right).

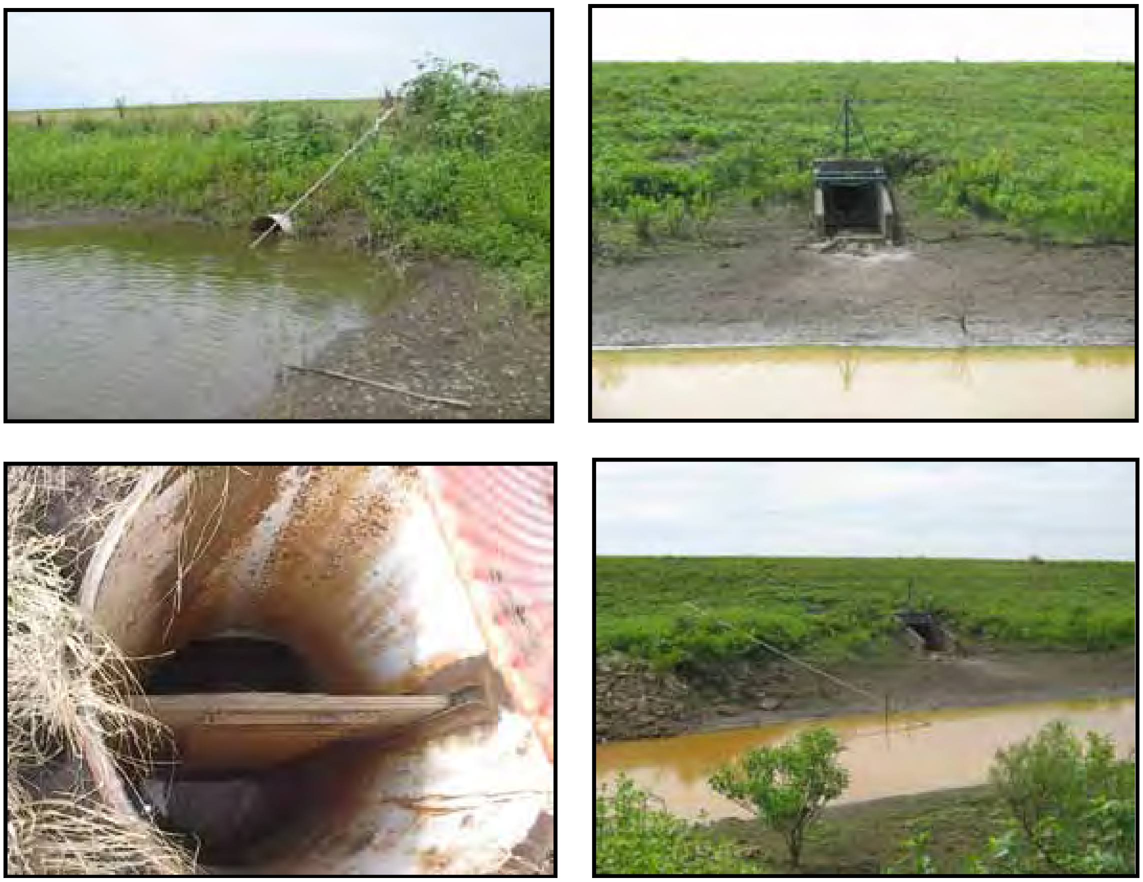

Figure 10.39.4 – L-246 Palmer Creek side ditch through tieback berm. Inlet for 36-in. culvert through tieback berm with datalogger (top left). Outlet for 36-in. culvert through tieback berm (top right). Stoplog structure at centerline of tieback berm (bottom left). Outlet of tieback levee draining to Palmer Creek with landside datalogger shown (bottom right).

Table 10.39.1 – L-246 Palmer Creek results

Spring Pulse from Gavins Point Dam	*May-09*	*Mar-08*
Created spring rise, ft	0	0
Estimated created spring rise flow, kcfs	0	0
Estimated MR flow at site, kcfs	66	-
% of MR flow	0	0
MD Outlet-flow threshold (Flanking Boxes)	*May-09*	*Mar-08*
Elev, ft	615.24	615.24
Estimated MR flow at site, kcfs	64	62
MD Inlet-flow threshold (Flanking Boxes)	*May-09*	*Mar-08*
Elev, ft	616.50	616.50
Estimated MR flow at site, kcfs	75	69

Table 10.39.2 – L-246 Palmer Creek NSR socioeconomic impacts

2009 MD Impacts	*LS Flooding*	*Gate Closure*
Elev, ft	630.98	-
Total impact duration, dy	no flooding	0.1 – 3.6
Interpolated flow, kcfs	-	110
2008 MD Impacts	*LS Flooding*	*Gate Closure*
Elev, ft	630.98	620.5
Impact duration, dy	no flooding	6.7 – 40.3
Interpolated flow, kcfs	-	135
2009 SD Impacts	*LS Flooding*	*Stop-log Gate Closure*
Elev, ft	627.00	619.14
Impact duration, dy	no flooding	0.4 – 6.5
WE in main ditch, ft	-	620.03

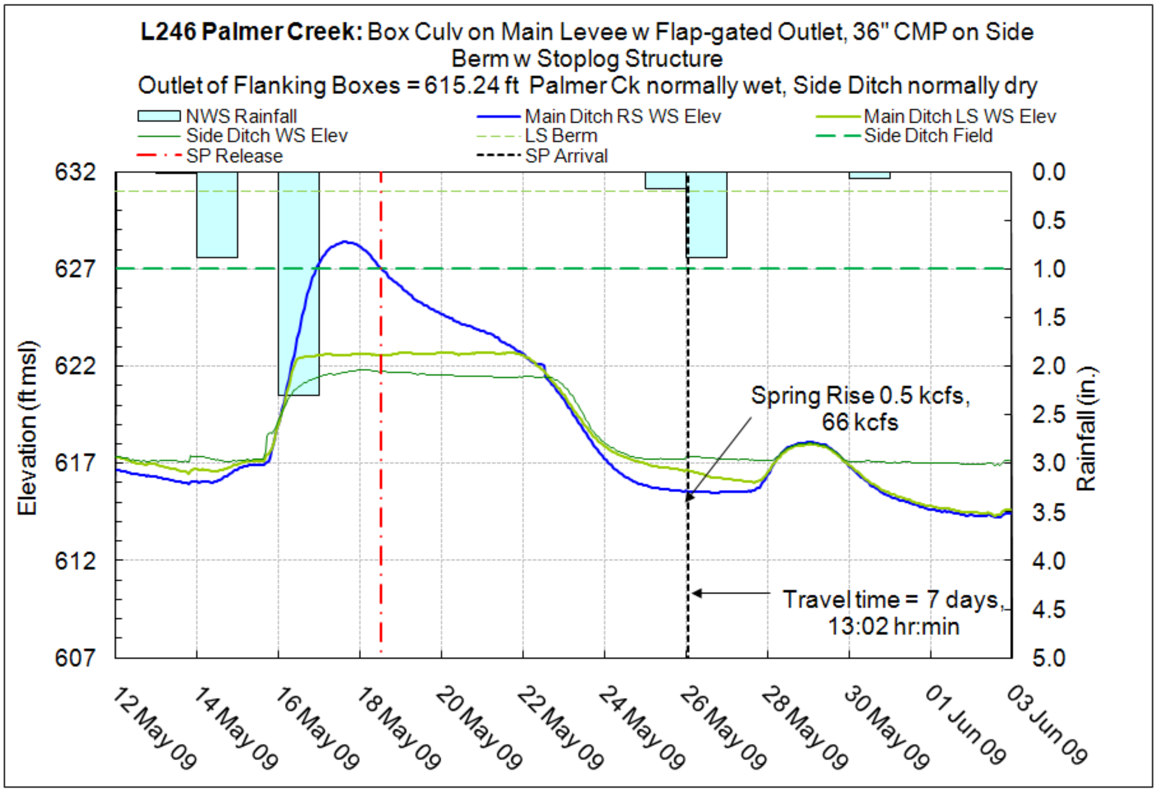

Figure 10.39.5 – Spring rise at L-246 Palmer Creek

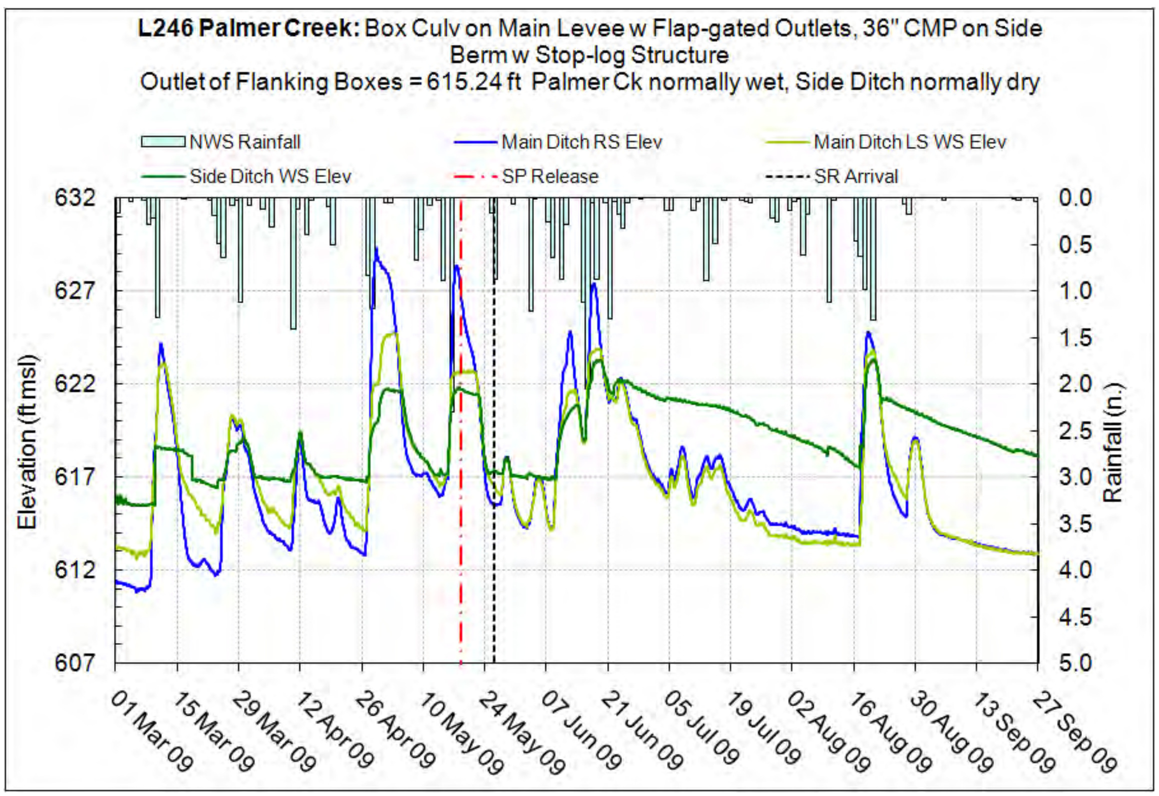

Figure 10.39.6 – Full monitoring record at L-246 Palmer Creek

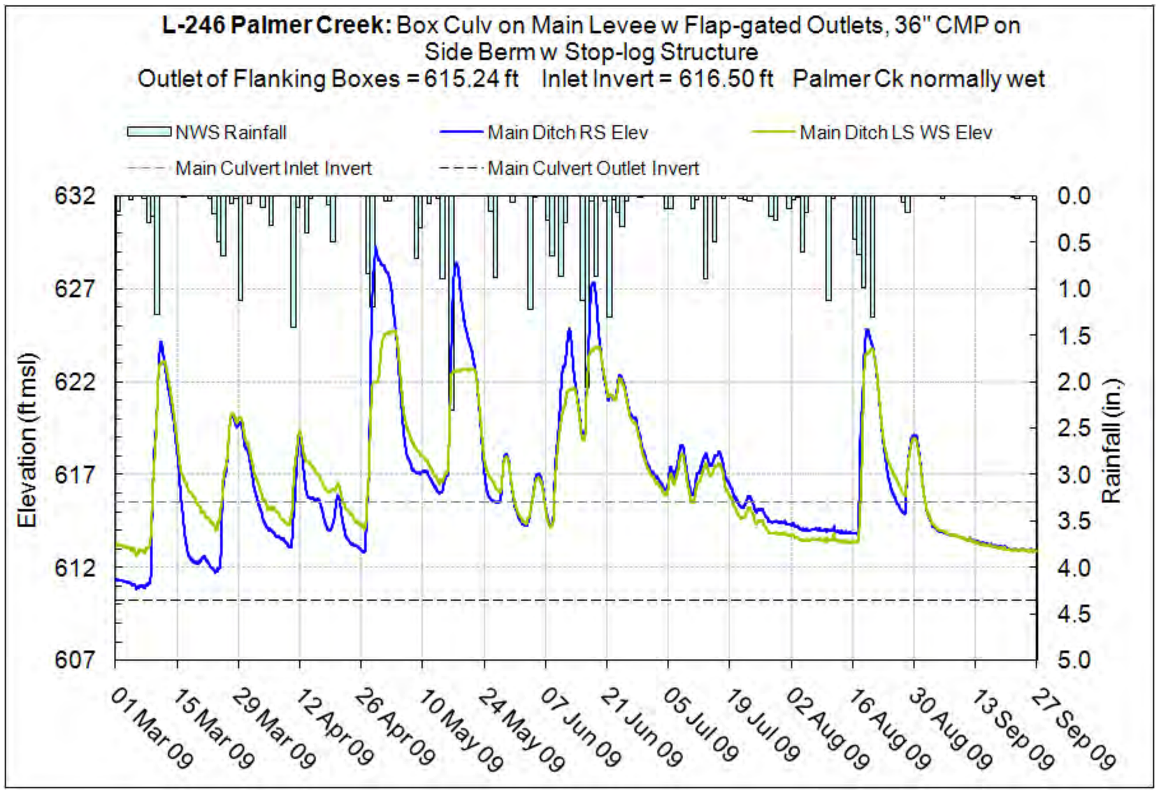

Figure 10.39.7 – Invert elevations of main culvert, L-246 Palmer Creek

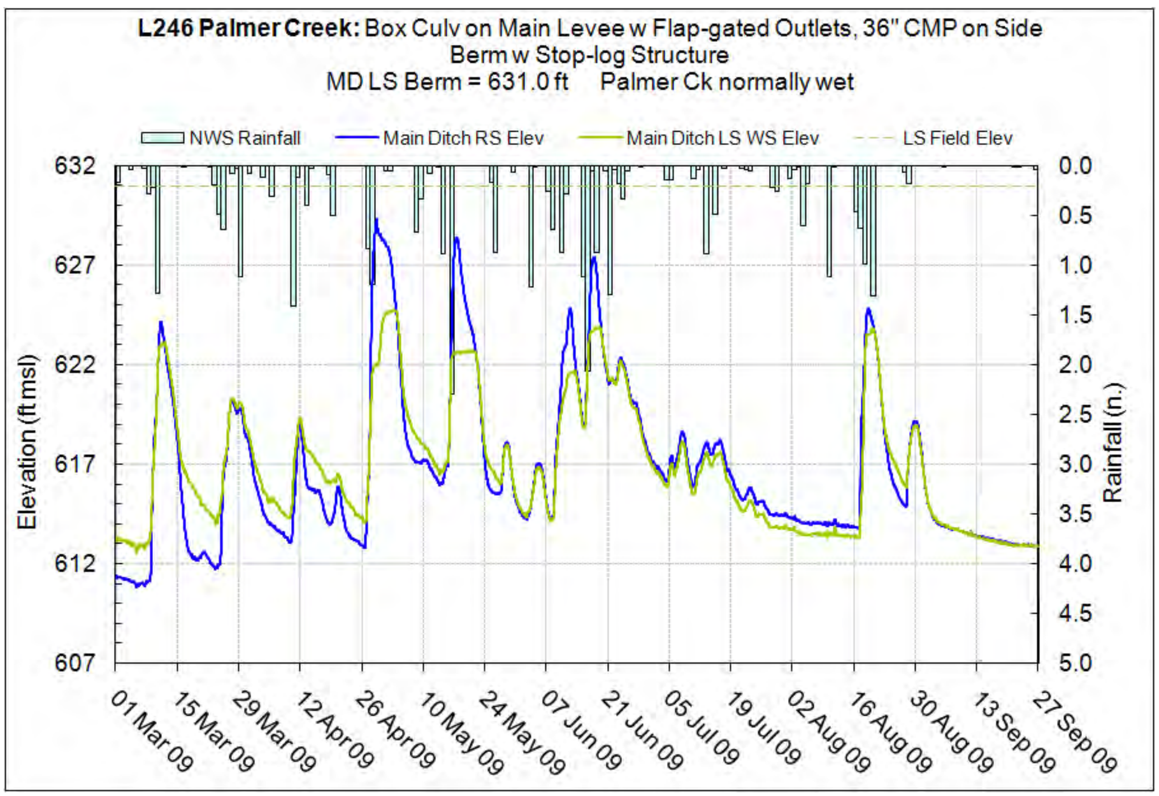

Figure 10.39.8 – Surveyed field elevations of main culvert, L-246 Palmer Creek

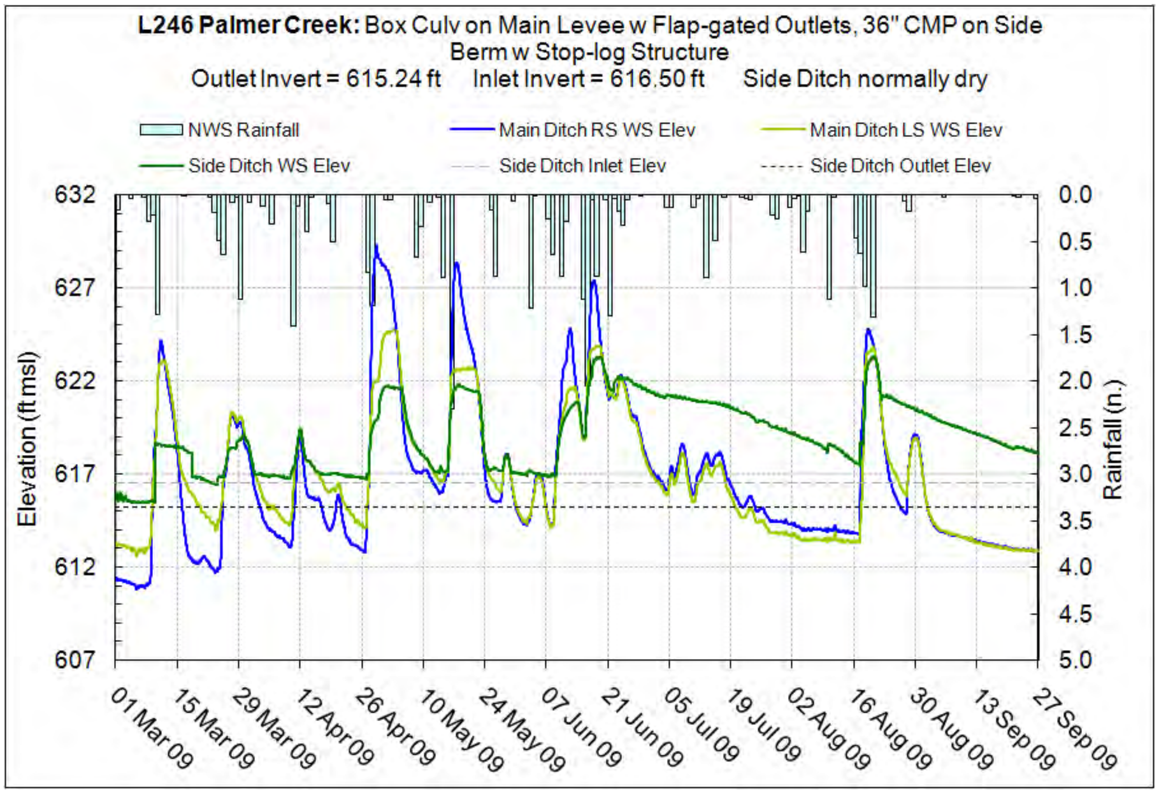

Figure 10.39.9 – Invert elevations of side ditch, L-246 Palmer Creek

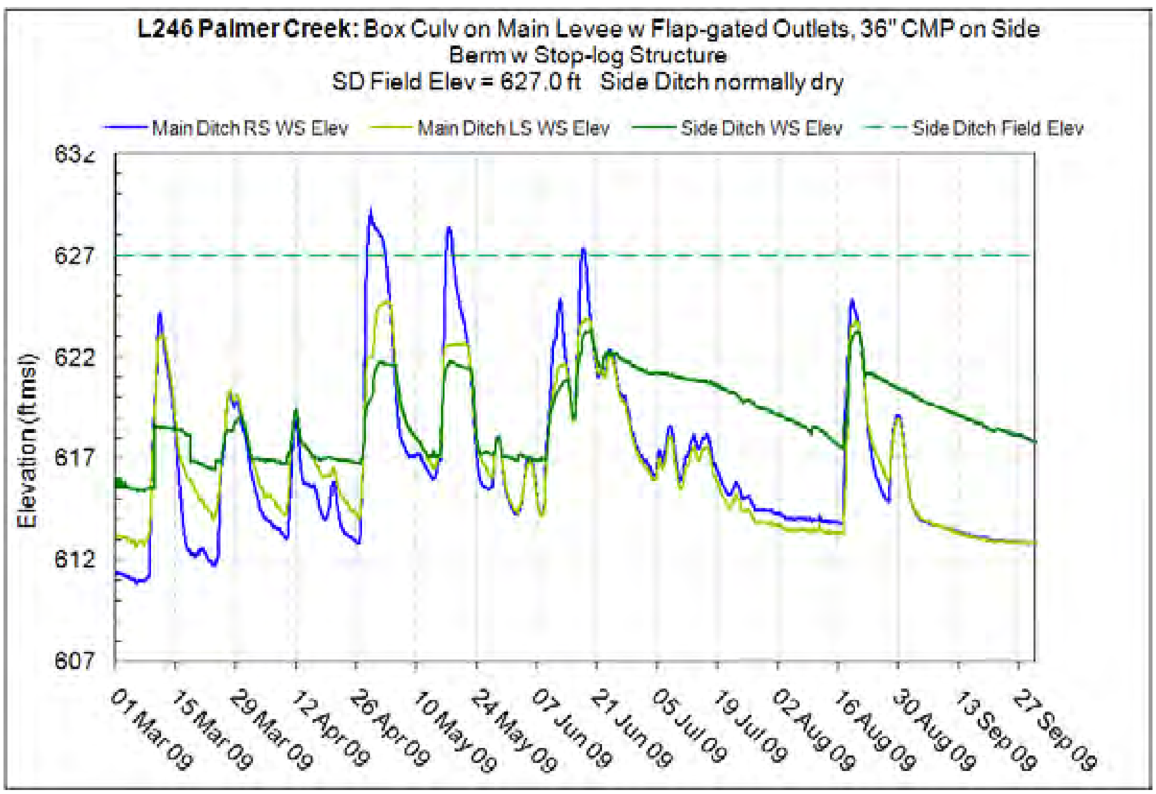

Figure 10.39.10 – Surveyed field elevations of side ditch, L-246 Palmer Creek

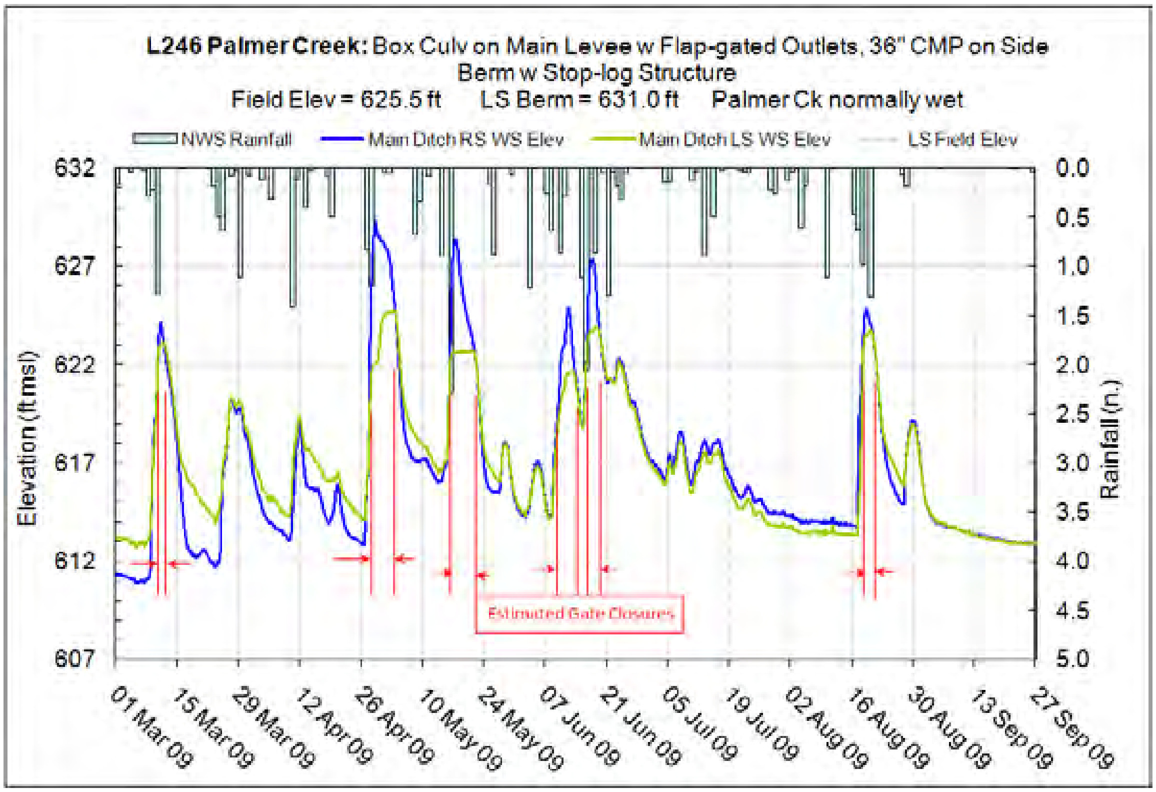

Figure 10.39.11 – NSR socioeconomic impacts on main ditch, L-246 Palmer Creek

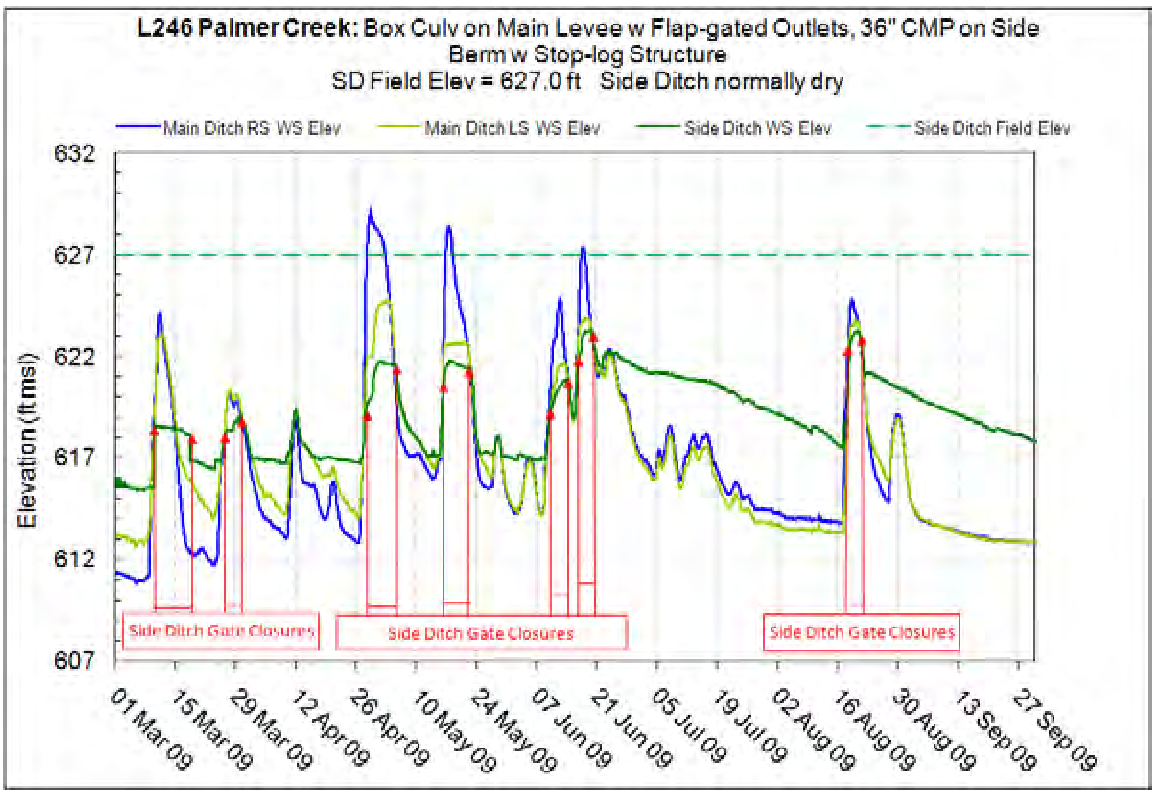

Figure 10.39.12 – NSR socioeconomic impacts of side ditch, L-246 Palmer Creek

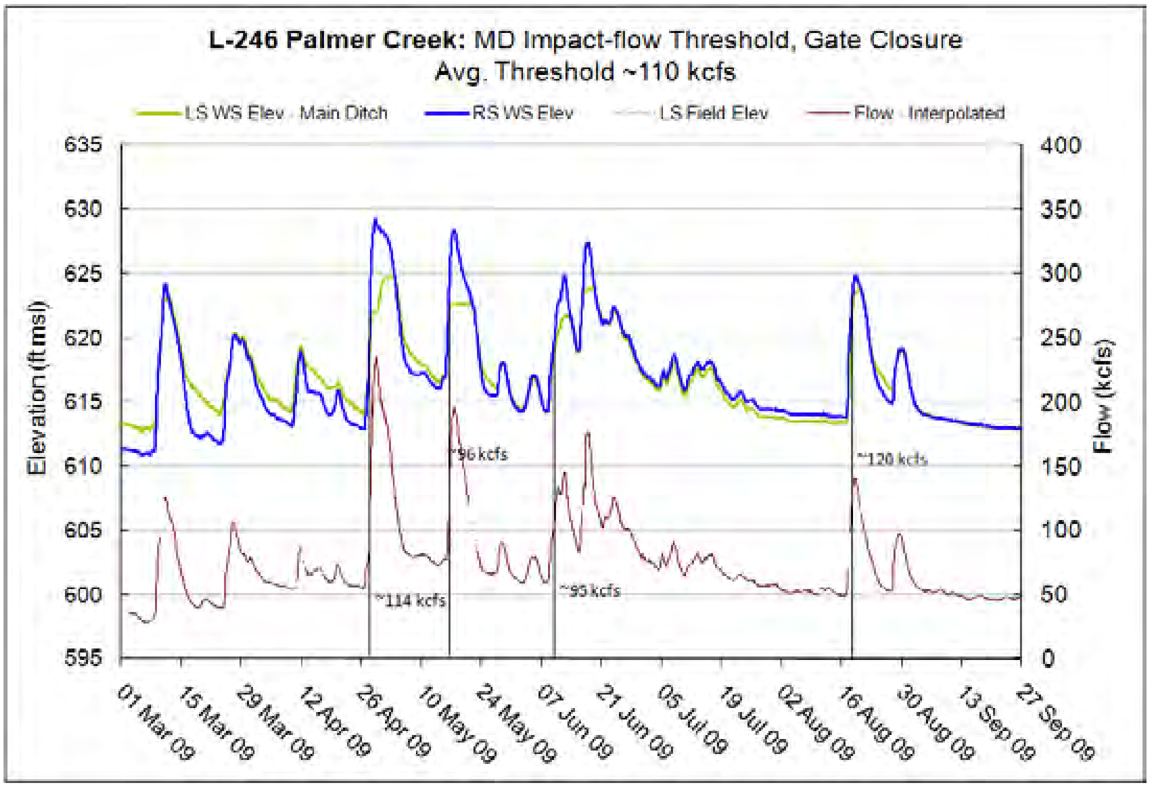

Figure 10.39.13 – NSR impact-flow thresholds (gate closure on main culvert), L-246 Palmer Creek

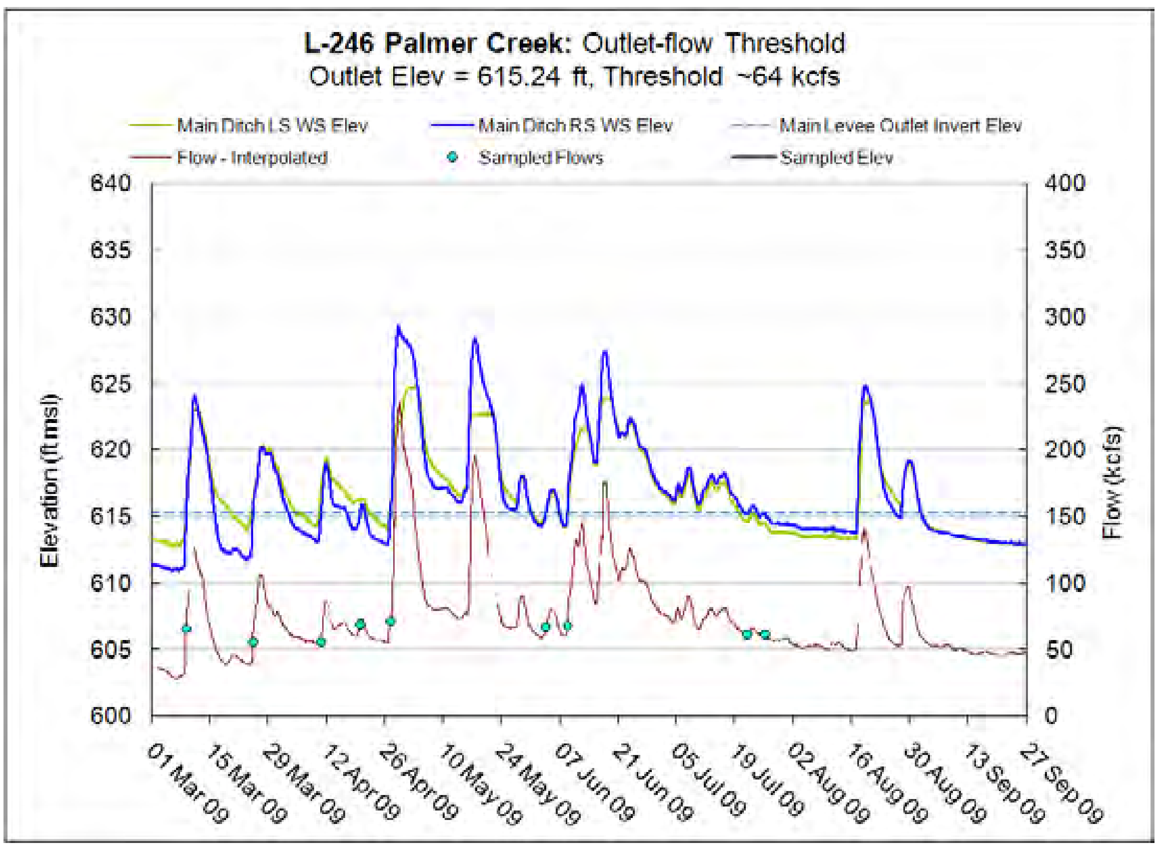

Figure 10.39.14 – Main ditch outlet-flow threshold, L-246 Palmer Creek

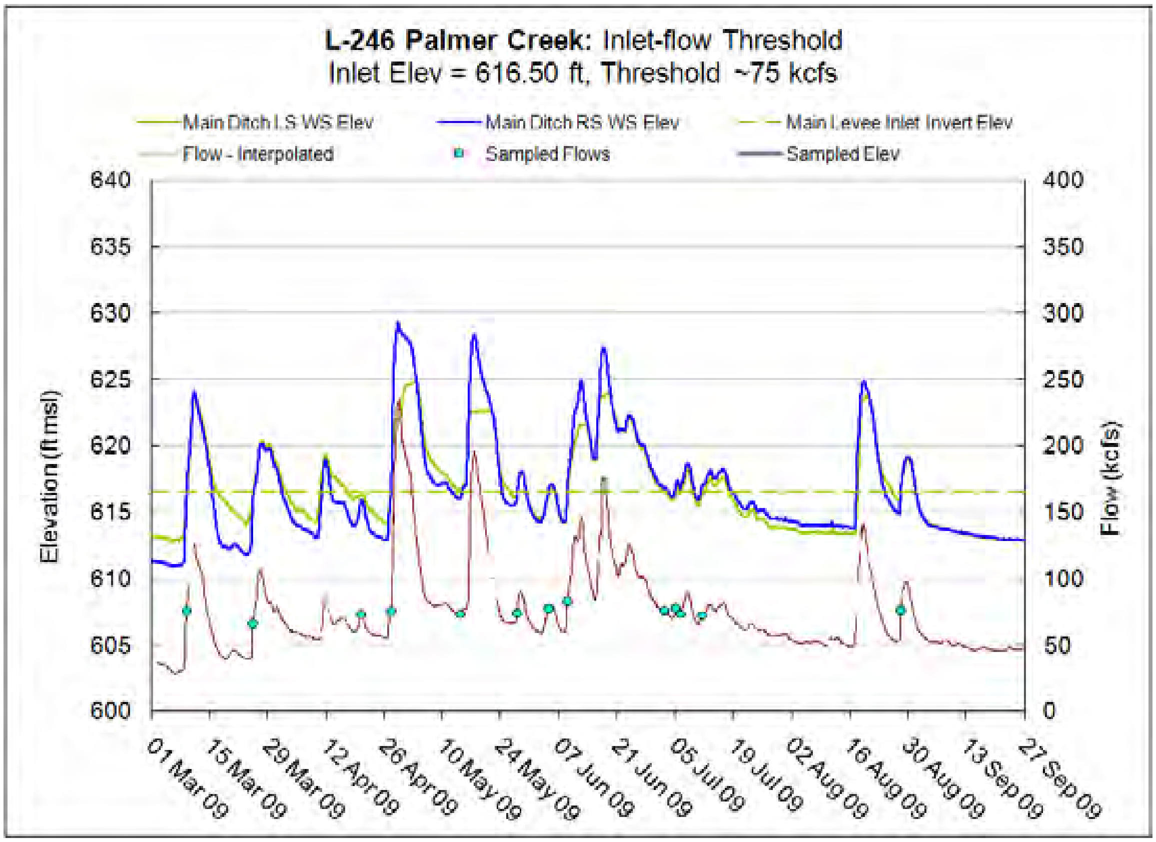

Figure 10.39.15 – Main ditch inlet-flow threshold, L-246 Palmer Creek

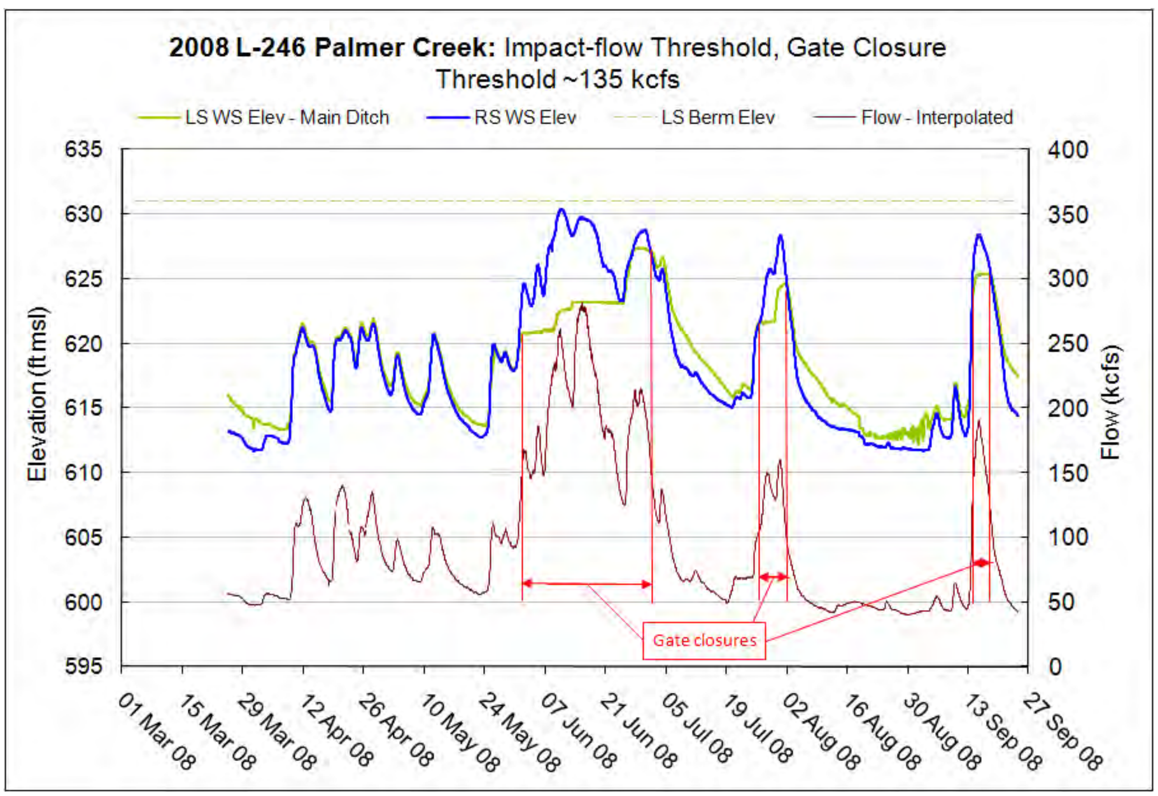

Figure 10.39.16 – Main ditch impact-flow threshold (gate closure), L-246 Palmer Creek (2008 record)

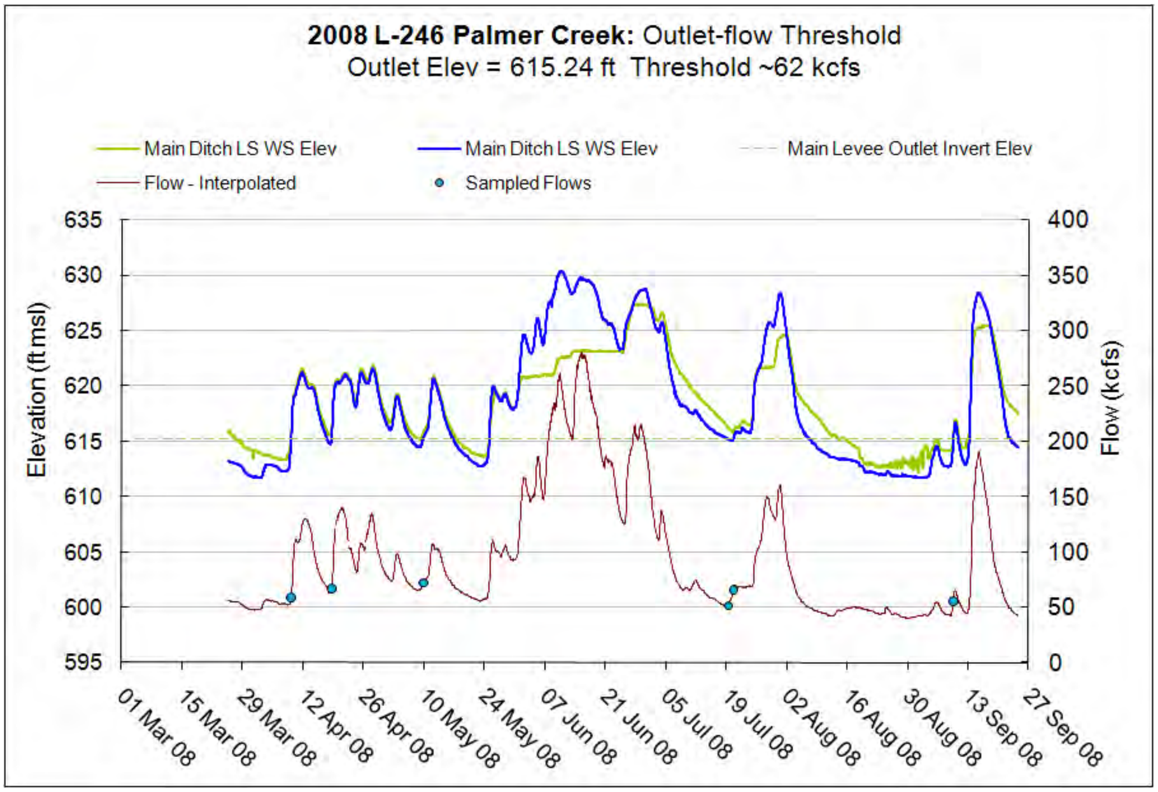

Figure 10.39.17 – Main ditch outlet-flow threshold, L-246 Palmer Creek (2008 record)

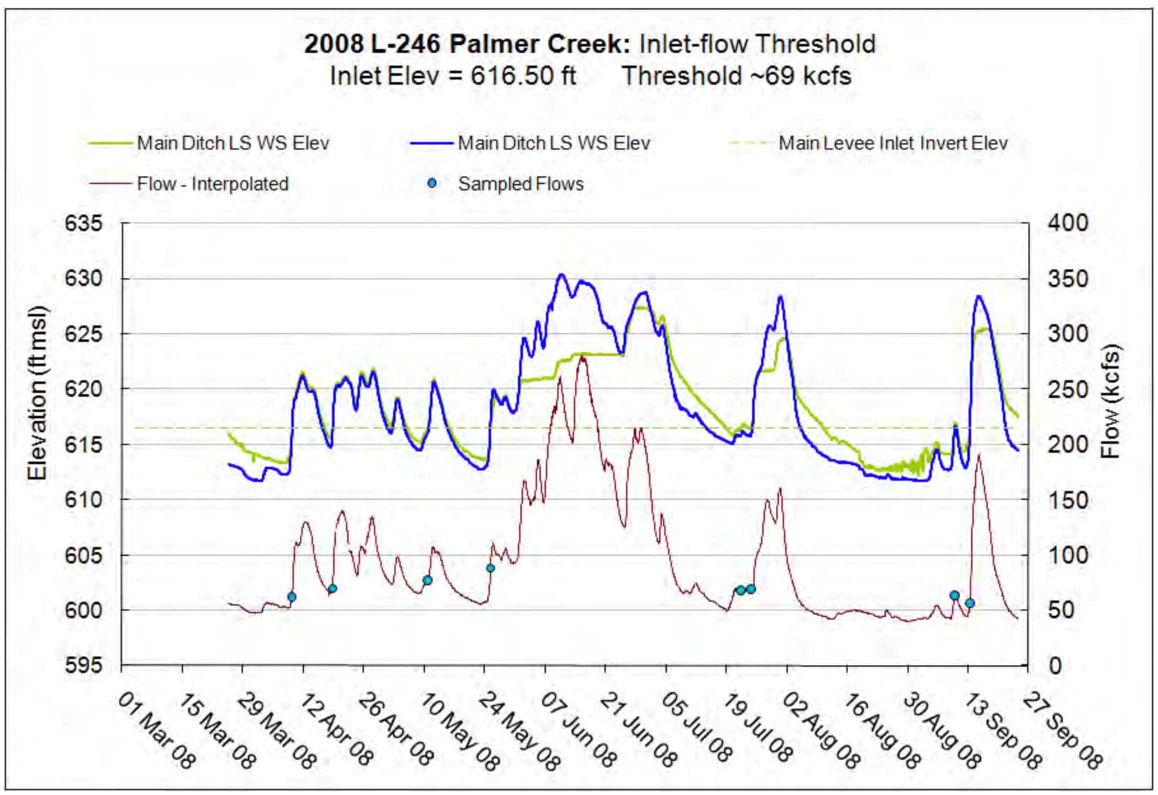

Figure 10.39.18 – Main ditch inlet-flow threshold, L-246 Palmer Creek (2008 record)

10.40 L-246 Dalton Ditch

The L-246 Dalton Ditch supplemental site is located at RM 239.4 on the north bank of the Little Missouri Bend of the Missouri River in Chariton County, MO just upstream of the Missouri River confluence with the Chariton River (Figure 10.40.1). The main drainage structure at this site is a single 54-in. CMP culvert through the main levee with an open inlet and a headwall to the inlet drainage ditch and a flap-gated outlet to a 780-ft drainage ditch draining to the Missouri River (Figure 10.40.2). The inlet ditch has berms on both sides and the access road to the Dalton Boat Ramp is on the left-bank berm. The inlet invert of the 54-in. CMP has an elevation of 614.10 ft and the outlet invert has an elevation of 612.96 ft. A pump station is located near the main drainage structure, and the pump is configured to pump on either the main ditch or the side ditch. The pump station has a 36-in. steel pipe that empties on the RS of the main levee and intakes on both the main and side ditches.

In addition to the drainage structure through the main levee, the L-246 Dalton Ditch site has a 48-in. CMP through the right bank side berm (Figure 10.40.3). The side-ditch culvert has a flap-gated outlet and an open inlet. The inlet invert of the 48-in. CMP is 614.46 ft and the outlet invert is 614.00 ft.

Field elevations were surveyed. The crest of the tieback berm on the LS right bank of the main ditch has a surveyed elevation of 626.8 ft. The typical field elevation of US fields on either side of the main ditch is 622.0 ft. The access road along the left bank of the main ditch to the Dalton Boat Ramp was not surveyed as the fields on the right bank were not cultivated. The typical field elevation on either side of the side ditch is also 622.0 ft.

Three data loggers were installed. One data logger was installed at the inlet of the 54-in. CMP on the main ditch (Figure 10.40.2 top left), a second was installed at the inlet of the 48-in. CMP on the side ditch (Figure 10.40.3 top left), and the third was installed about 100-ft downstream of the main levee (Figure 10.40.2 bottom right) where the outlet drainage ditch enters the Missouri River. Flows were estimated at the site by lagging the flow record of the Grand River at Sumner to the Missouri River, adding it to the lagged flow record of USGS Waverly, and then lagging the resulting record to the site.

Results and Discussion

- Table 10.40.1 summarizes the results for the May 2009 created spring rise, and the Missouri River flows estimated to reach the outlet and inlet of 54-in. CMP of the drainage structure.
- Table 10.40.2 summarizes the socioeconomic impacts produced by the natural spring rises at the site in May 2009. Socioeconomic impacts to the RS of the site were not considered because the fields do not appear to be cultivated. Gate closures varied between 0.6 of a day to a little over 4 days.
- Figure 10.40.4 shows the spring pulse release on May 18 and its travel time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise created by the spring pulse could not be identified from other effects at this site. Based on the attenuation analysis, the spring pulse accounts for 0 kcfs of the total 66-kcfs Missouri-River flow at this river mile, or 0% of the total flow.
- Figure 10.40.5 shows the full monitoring records of all three data loggers with the time of the May spring pulse’s release and its travel time to the site.
- Figure 10.40.6 shows inlet and outlet invert elevations of the 54-in. CMP through the main levee.

- Figure 10.40.7 shows the typical LS field elevation surveyed in 2009. The typical field elevation at this site is 622.0 ft. Cultivated fields, however, are protected on the right bank of the site by the tieback berm which has an elevation of 626.8 ft and the fields beyond the access road on the left bank of the main ditch are not cultivated. The tieback berm elevation (626.8 ft), therefore, was used to determine socioeconomic impacts on the main ditch at the site.
- Figure 10.40.8 shows possible socioeconomic impacts produced by natural spring rises on the main ditch of the site during the monitoring period. There were no identified socioeconomic impacts at this site during the 2009 monitoring period.
- Figure 10.40.9 shows the estimation of the outlet-flow threshold for the main drainage structure. The flow in the Missouri River at the site required to reach the outlet of the site is estimated to be 64 kcfs at the site.
- Figure 10.40.10 shows the estimation of the inlet-flow threshold for the main drainage structure. The flow in the Missouri River at the site required to reach the inlet of the site is estimated to be 73 kcfs at the site.
- Figure 10.40.11 shows the inlet and outlet invert elevations of the 48-in. CMP side ditch.
- Figure 10.40.12 shows the typical 622.0-ft field elevation of the side ditch fields.
- Figure 10.40.13 shows there was pumping on the side ditch. The duration of pumping was about 19 days. Pumping appears to be in response to rainfall in early June 2009.

Conclusions

No socioeconomic impacts were produced at this site by the created spring rise. The rise produced by the created spring pulse could not be separated from background effects on the river. Based on the attenuation analysis, the spring pulse accounts for 0 kcfs of the total 66 kcfs Missouri-River flow at this river mile, or 0% of the total flow. Pumping occurred on the side ditch in response to rainfall in early June.

Figure 10.40.1 – L-246 Dalton Ditch location

Figure 10.40.2 – L-246 Dalton Ditch main levee. Inlet of 54-in. culvert with landside data logger (top left). Outlet of 54-in. culvert through main levee and pump station outlet (top right). Top of levee looking riverward (bottom left). River data logger on bank (bottom right).

Figure 10.40.3 – Side ditch culvert through L-246 Dalton Ditch berm. Inlet of 48-in. culvert through right bank side berm with data logger (top left). Outlet of 48-in. culvert with flap gate (top right). Side ditch with pump station looking landward (bottom left). Dalton boat ramp looking downstream (bottom right).

Table 10.40.1 – L-246 Dalton Ditch results

Spring Pulse from Gavins Point Dam	*May-09*	*Mar-08*
Created spring rise, ft	0	-
Estimated created spring rise flow, kcfs	0	-
Estimated MR flow at site, kcfs	66	-
% of MR flow	0	-

Main Ditch – Outlet-flow Threshold	*May-09*	*Mar-08*
Elev, ft	612.96	-
Estimated MR flow at site, kcfs	64	-

Main Ditch - Inlet-flow threshold	*May-09*	*Mar-08*
Elev, ft	614.1	-
Estimated MR flow at site kcfs	73	-

Table 10.40.2 – L-246 Dalton Ditch NSR socioeconomic impacts

Main Ditch Impacts	*LS Flooding*	*RS Flooding*	*Gate Closure*
Elev, ft	626.8	Not cultivated	Varies
Impact duration, dy	No flooding	-	0.6 – 4.4
Estimated MR flow at site, kcfs	-	-	99

Side Ditch Impacts	*LS & RS Flooding*	*Gate Closure*	*Pumping*
Elev, ft	622.0	616.1	616.5
Impact duration, dy	No flooding	2.9 – 18.6	15
WS Elev in Main ditch, ft	-	616.19	617.75

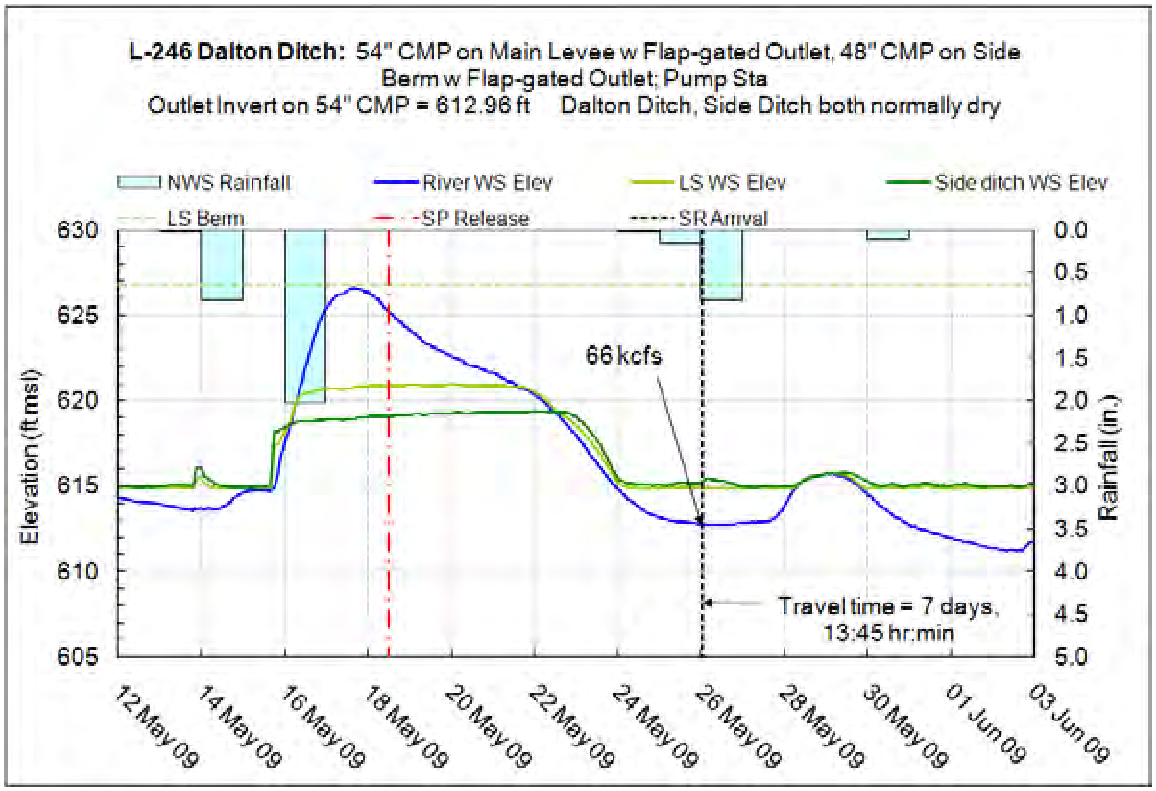

Figure 10.40.4 – Spring rise at L-246 Dalton Ditch

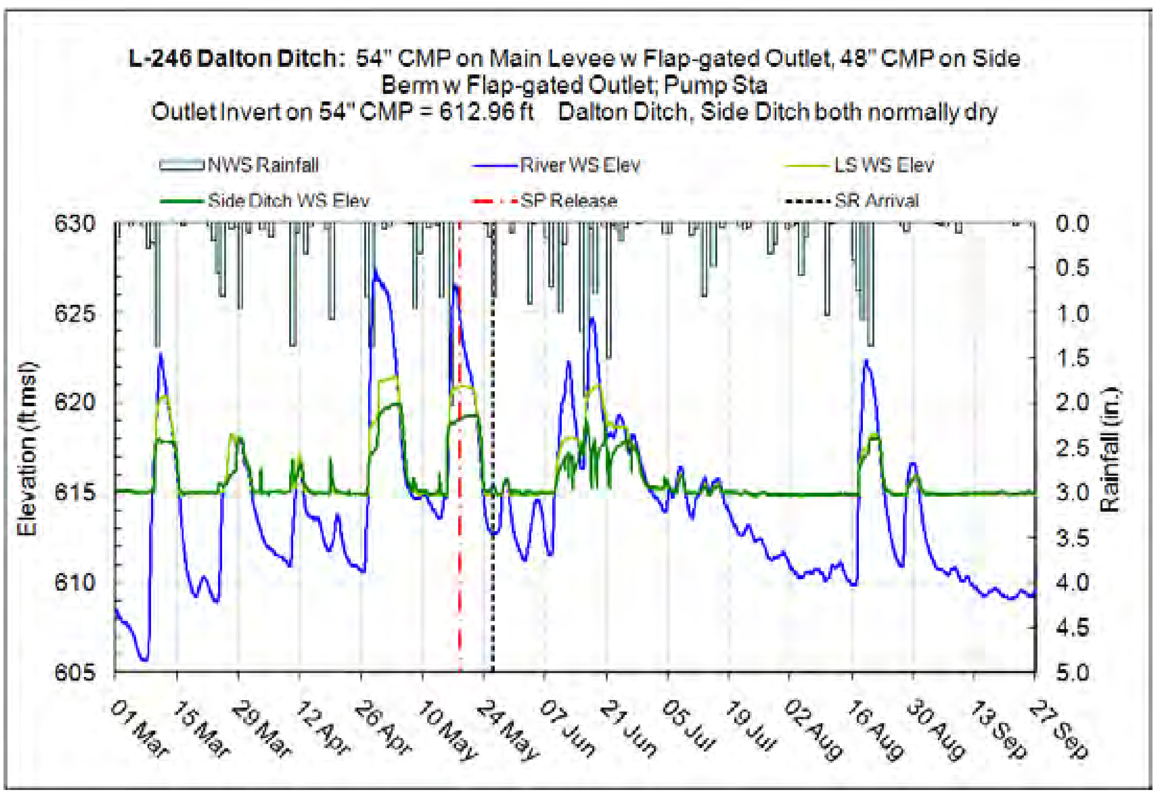

Figure 10.40.5 – Full monitoring record at L-246 Dalton Ditch

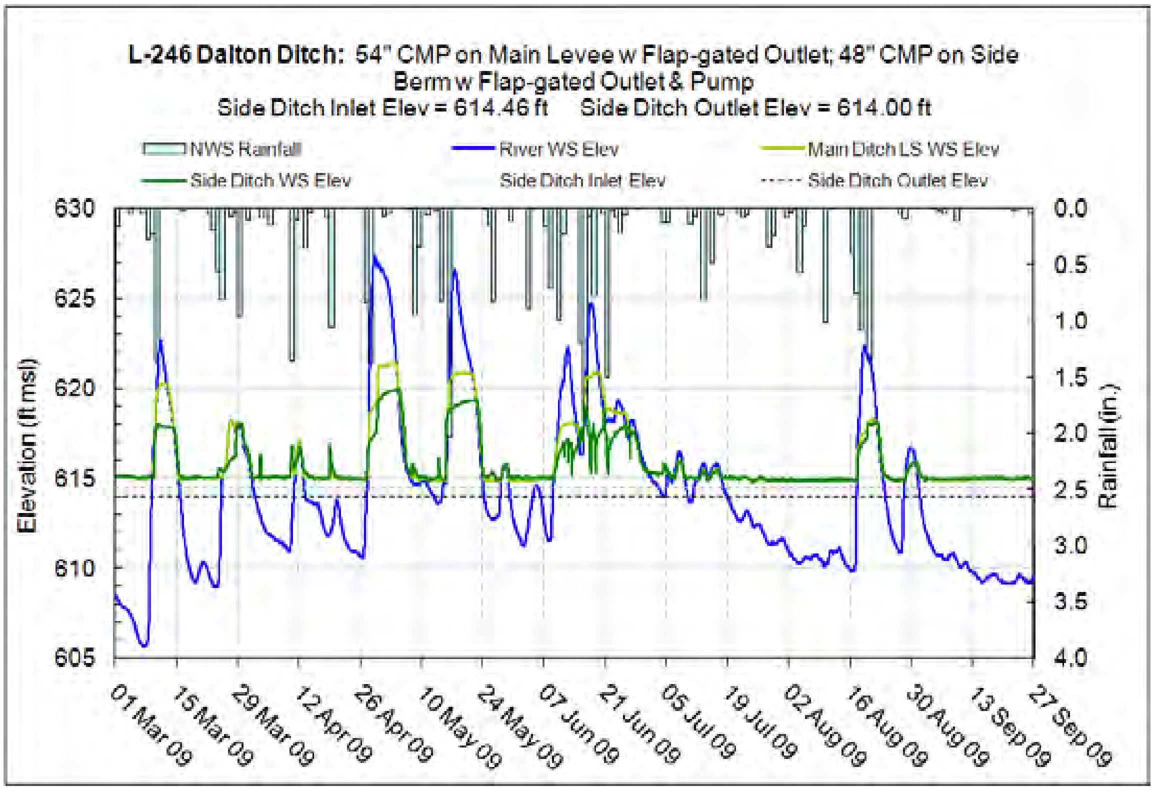

Figure 10.40.6 – Main ditch invert elevations, L-246 Dalton Ditch

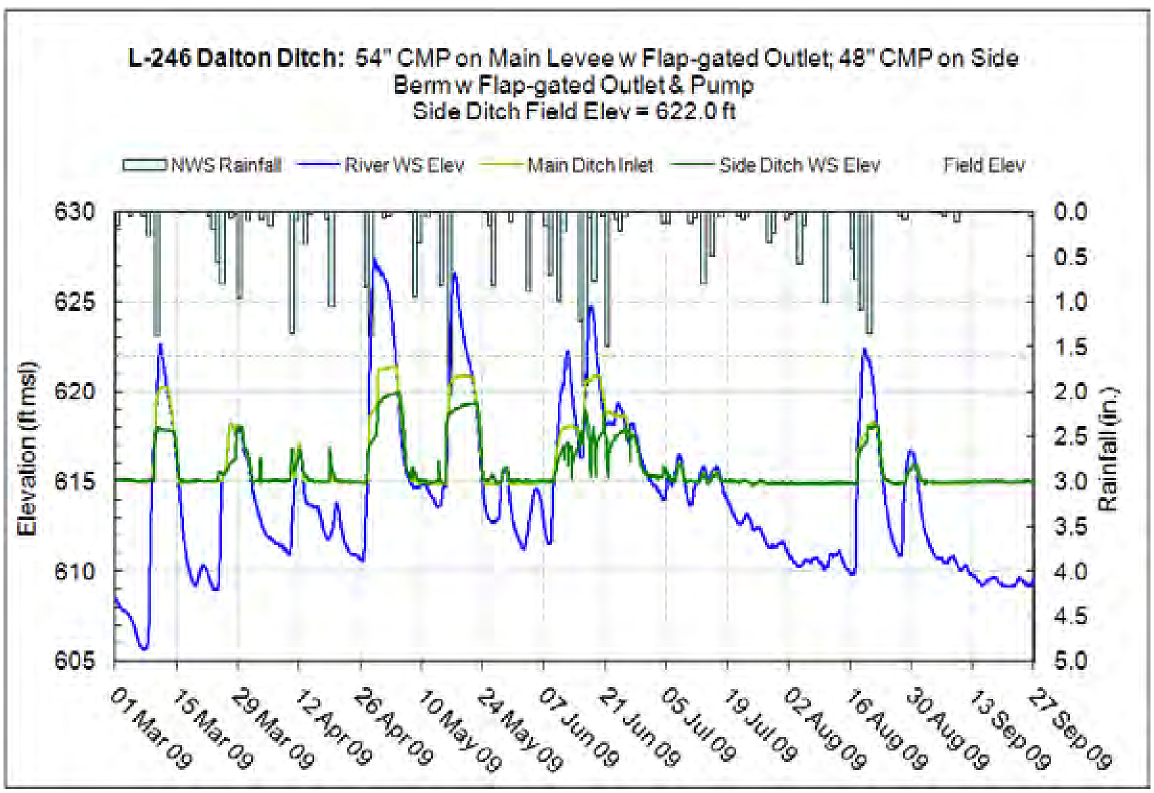

Figure 10.40.7 – Main ditch surveyed berm elevation, L-246 Dalton Ditch

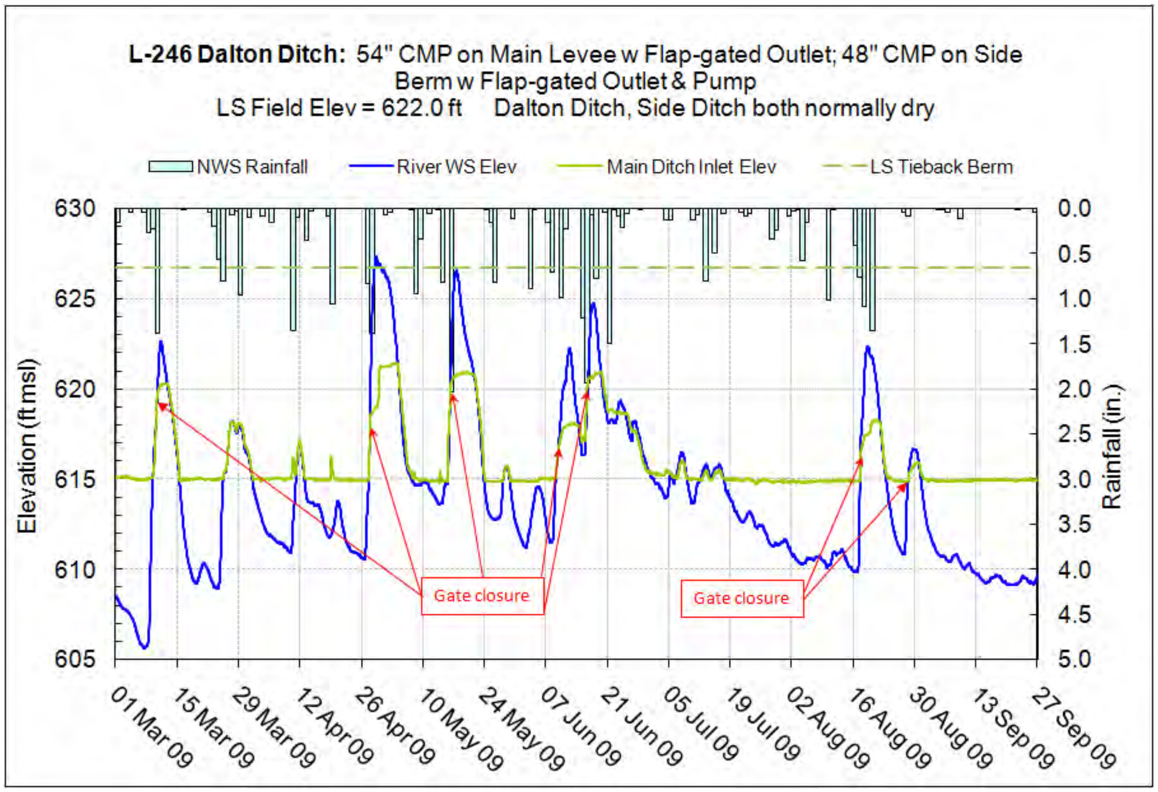

Figure 10.40.8 – Main ditch NSR socioeconomic impacts, L-246 Dalton Ditch

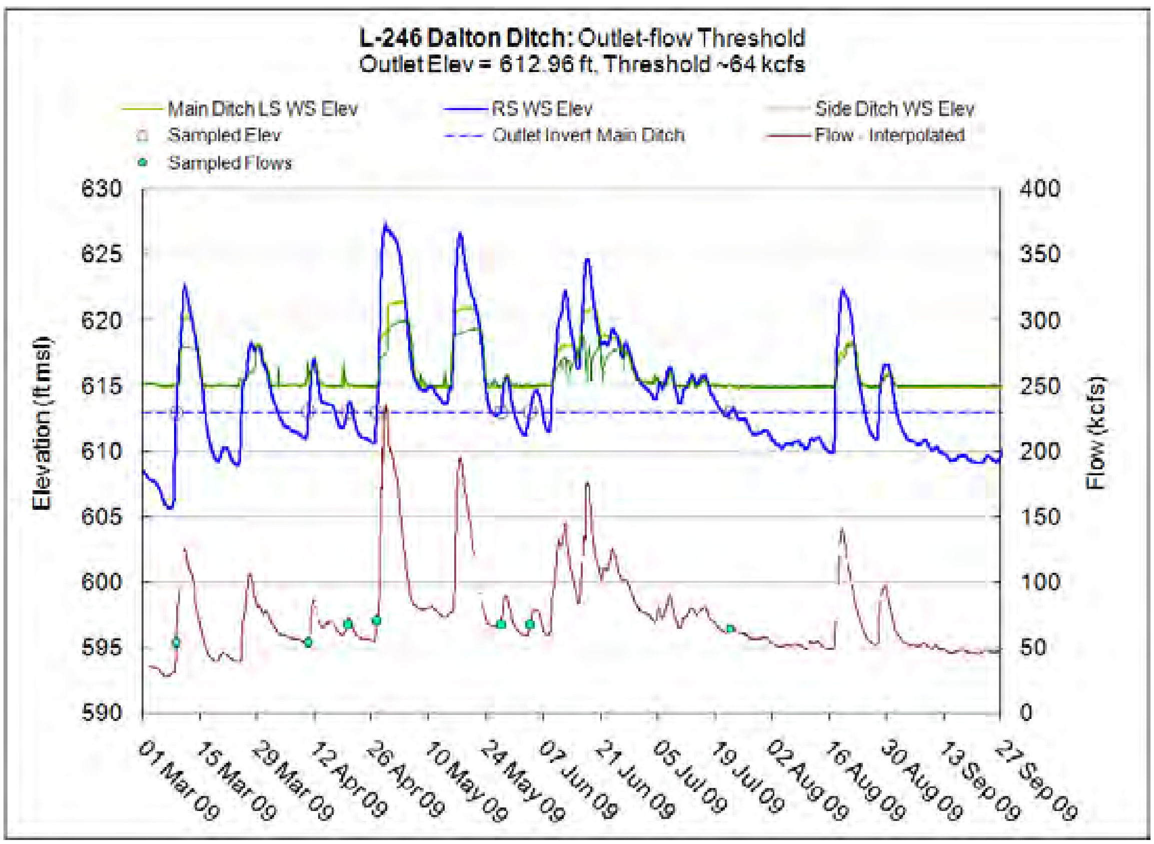

Figure 10.40.9 – Main ditch outlet-flow threshold, L-246 Dalton Ditch

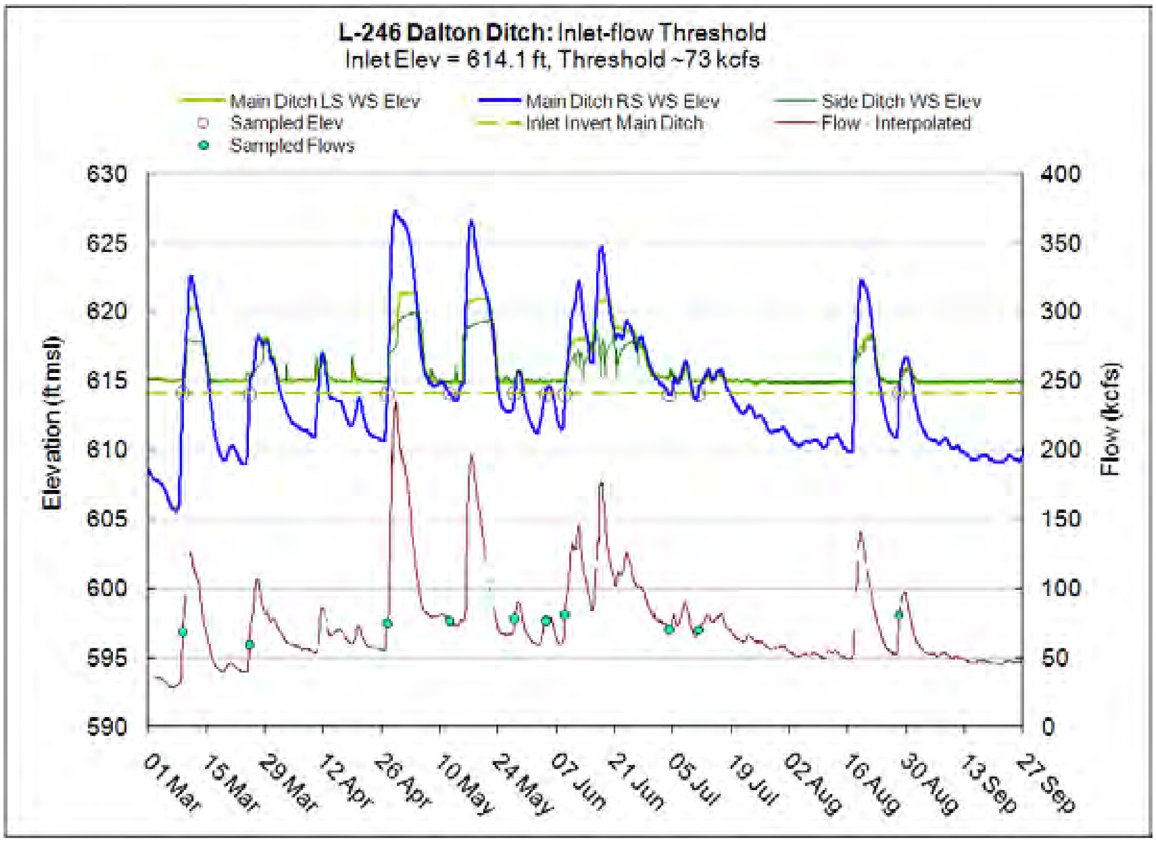

Figure 10.40.10 – Main ditch inlet-flow threshold, L-246 Dalton Ditch

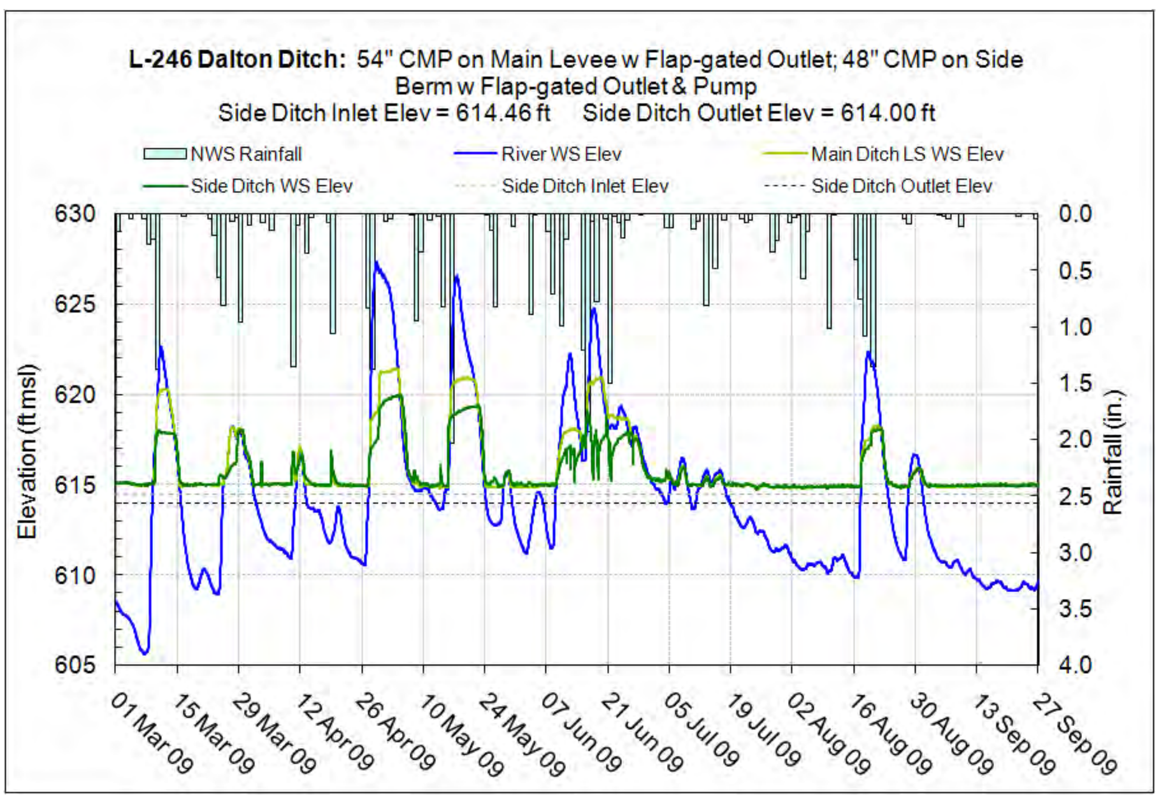

Figure 10.40.11 – Side ditch invert elevations of L-246 Dalton Ditch

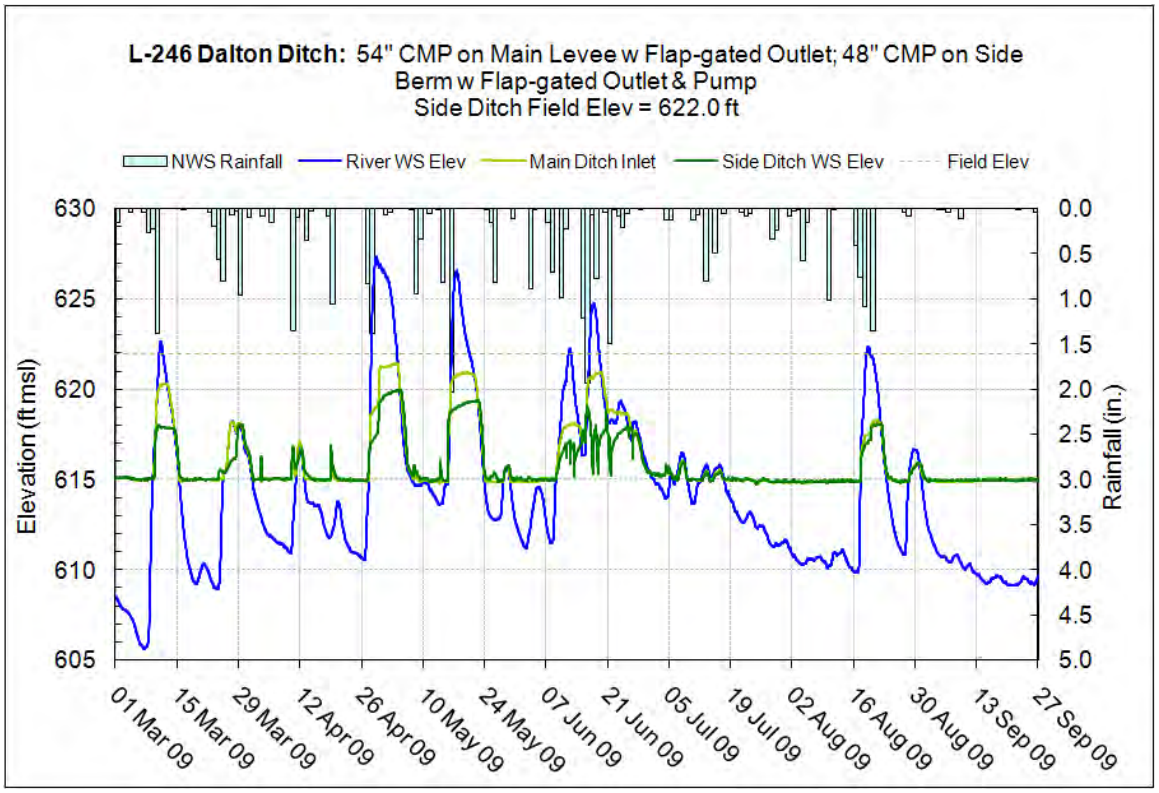

Figure 10.40.12 – Side ditch surveyed field elevations, L-246 Dalton Ditch

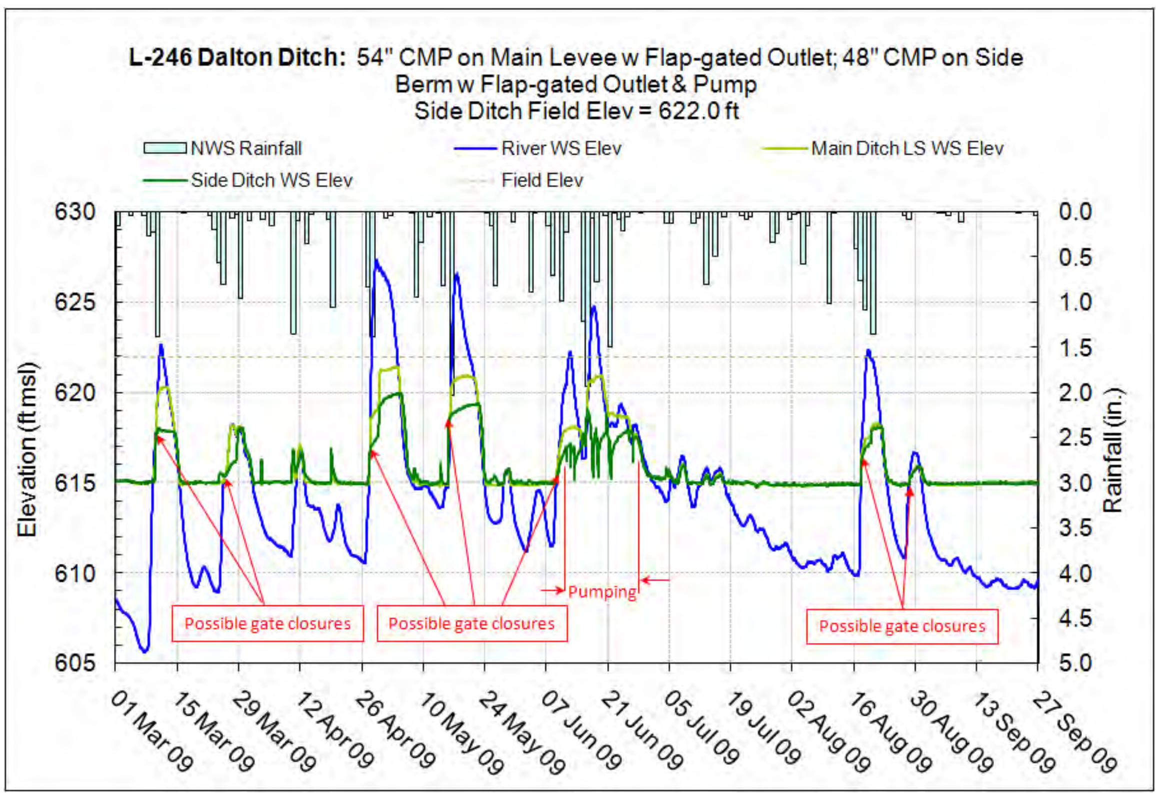

Figure 10.40.13 – Side ditch NSR socioeconomic impacts, L-246 Dalton Ditch

10.41 USACE Glasgow

The USACE Missouri River Glasgow gage is located west of Glasgow, MO downstream of the Highway 87 bridge at river mile 226.3 on the right bank of the Missouri River (Figure 10.41.1). Flood stage was exceeded three times by natural spring rises at the USACE Missouri River gage in 2009. All flood durations were less than one week.

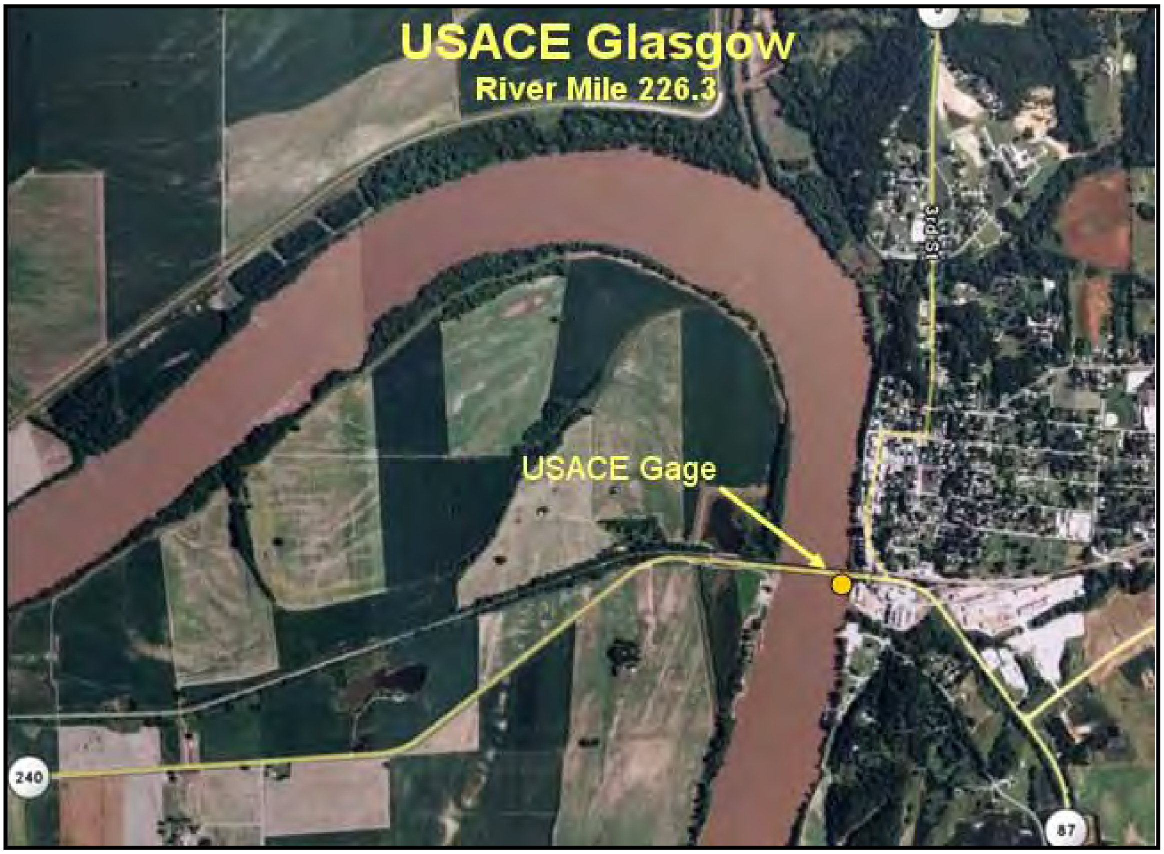

Figure 10.41.1 – USACE Glasgow location

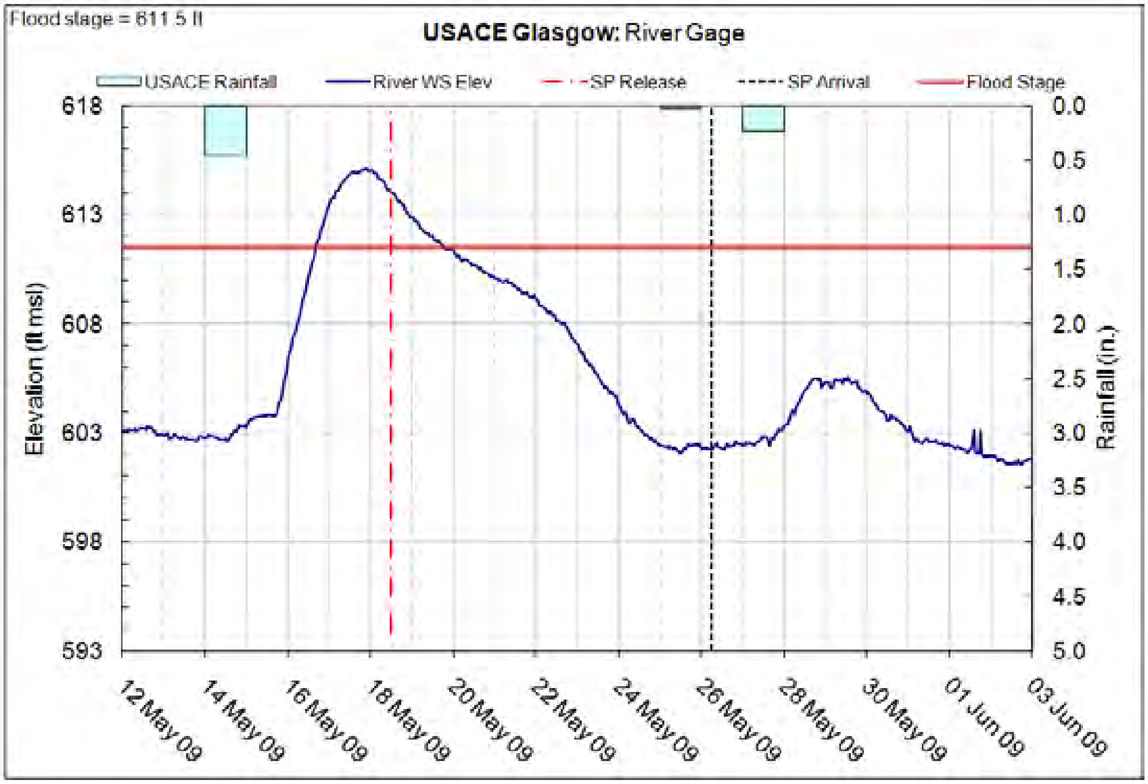

Figure 10.41.2 – Spring rise at USACE Glasgow

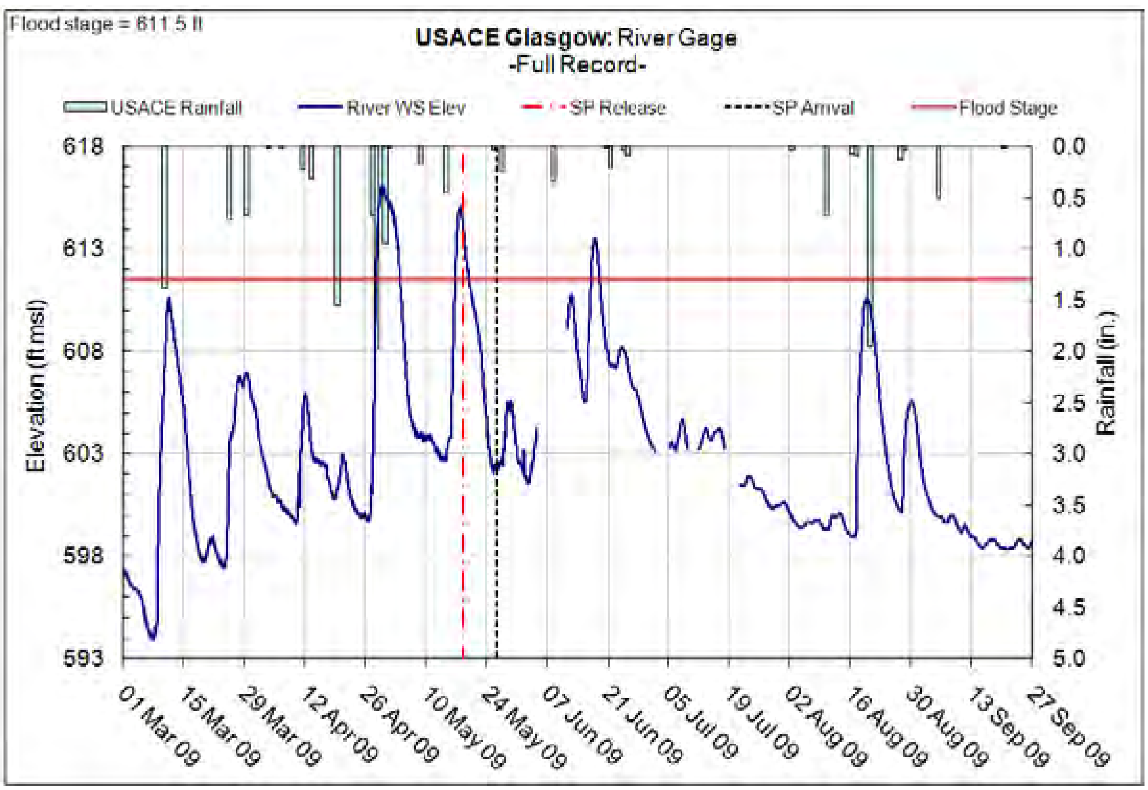

Figure 10.41.3 – Full monitoring record at USACE Glasgow

10.42 USGS Boonville

The USGS Missouri River Boonville gage is located at river mile 197.1 upstream of the railroad bridge to the north of Boonville, MO on the right bank of the Missouri River (Figure 10.42.1). Figure 10.40.2 shows the stage recorded at the USGS Boonville gage and precipitation recorded at the New Franklin 1W gage (ID 236012) in Howard County, MO (NCDC, 2008) in early April 2008. The rise in stage between April 3 and 5 is primarily the result of the natural increase of tributary inflows to the Missouri River and increased releases for navigation. Flood stage was exceeded three times by natural spring rises at the USACE Missouri River gage in 2009. All flood durations were less than one week.

Figure 10.42.1 – USGS Boonville location

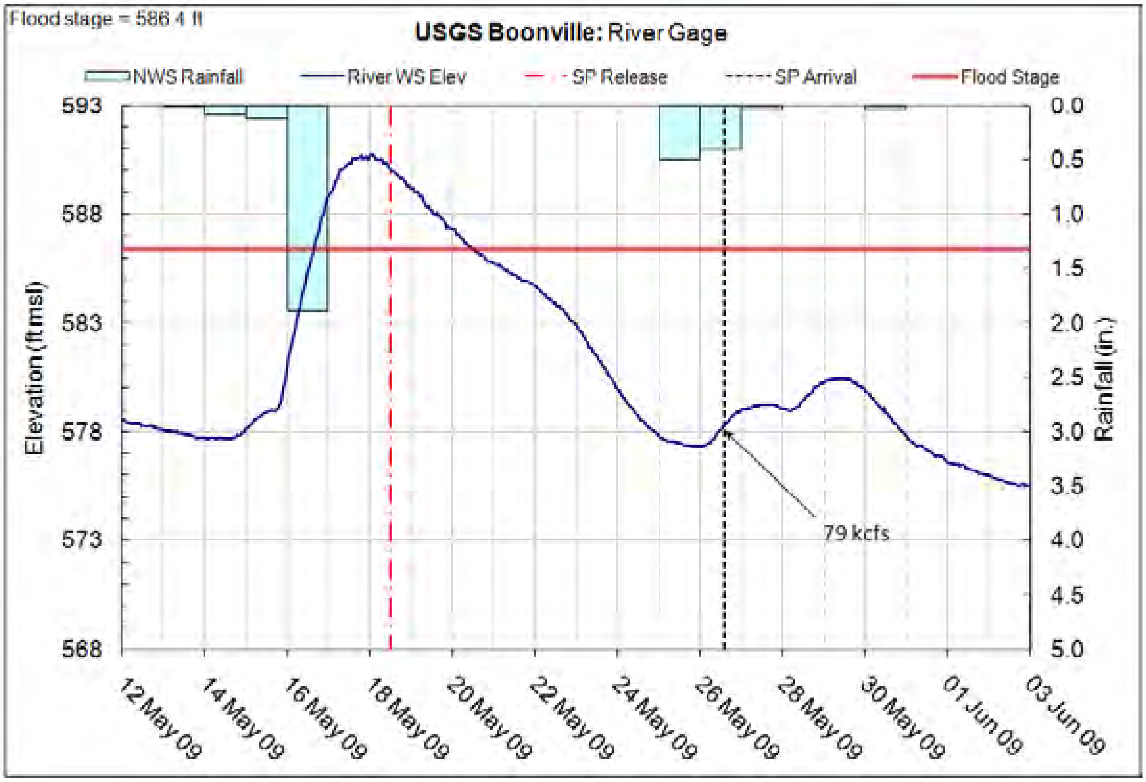

Figure 10.42.2 – Spring rise at USGS Boonville

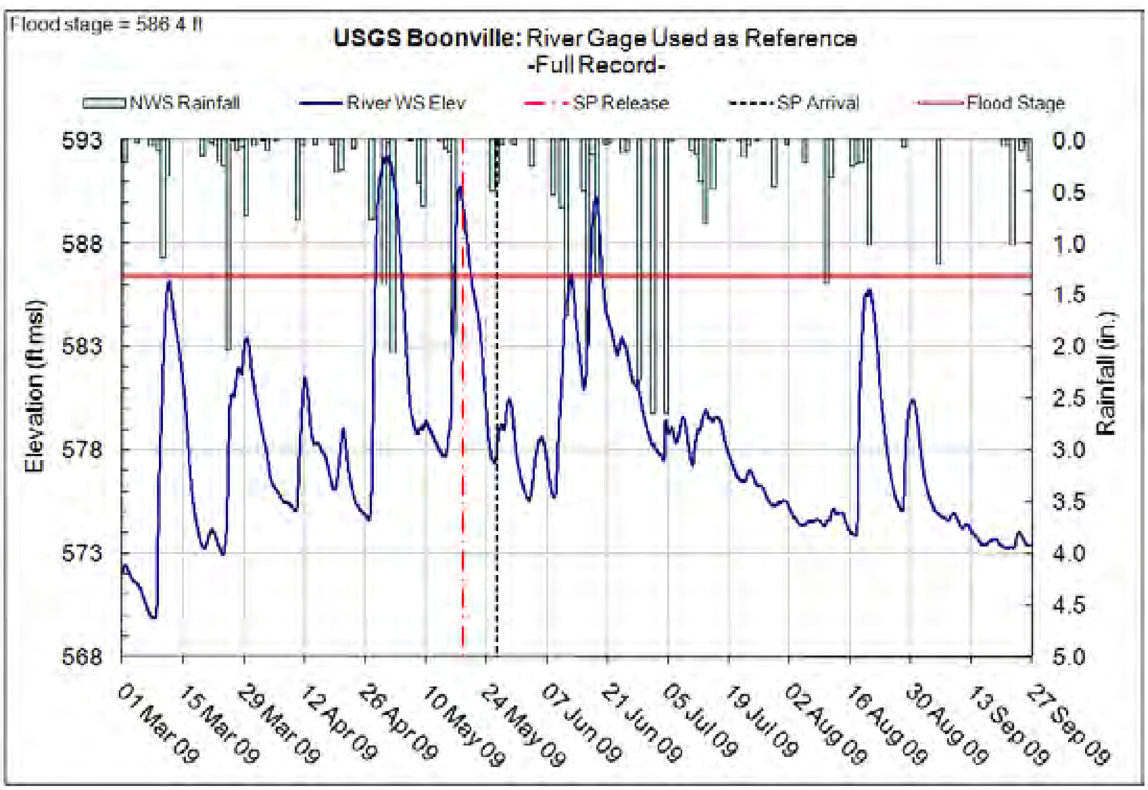

Figure 10.42.3 – Full monitoring record at USGS Boonville

10.43 USACE Jefferson City

The USACE Missouri River Jefferson City gage is located upstream of the Highway 63 and Highway 54 bridges at Jefferson City, MO at river mile 143.9 on the right bank of the Missouri River (Figure 10.43.1). Flood stage was exceeded three times by natural spring rises at the USACE Missouri River gage in 2009. All flood durations were less than one week.

Figure 10.43.1 – USACE Jefferson City location

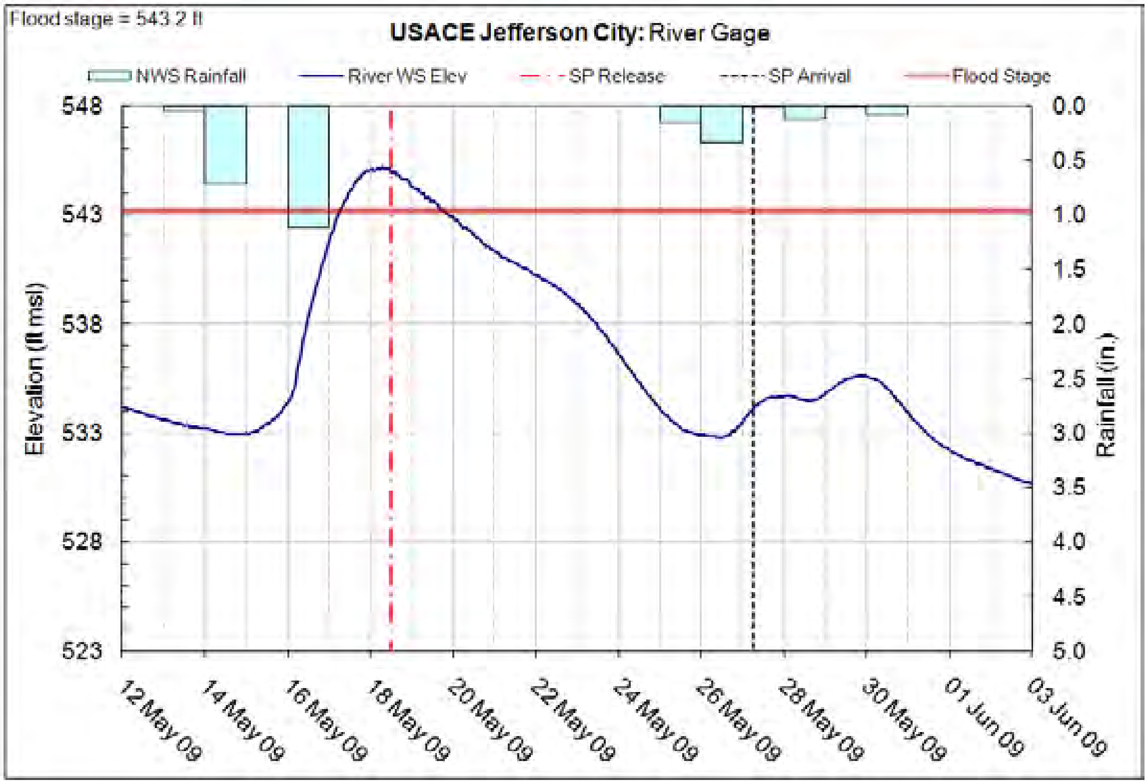

Figure 10.43.2 – Spring rise at Jefferson City

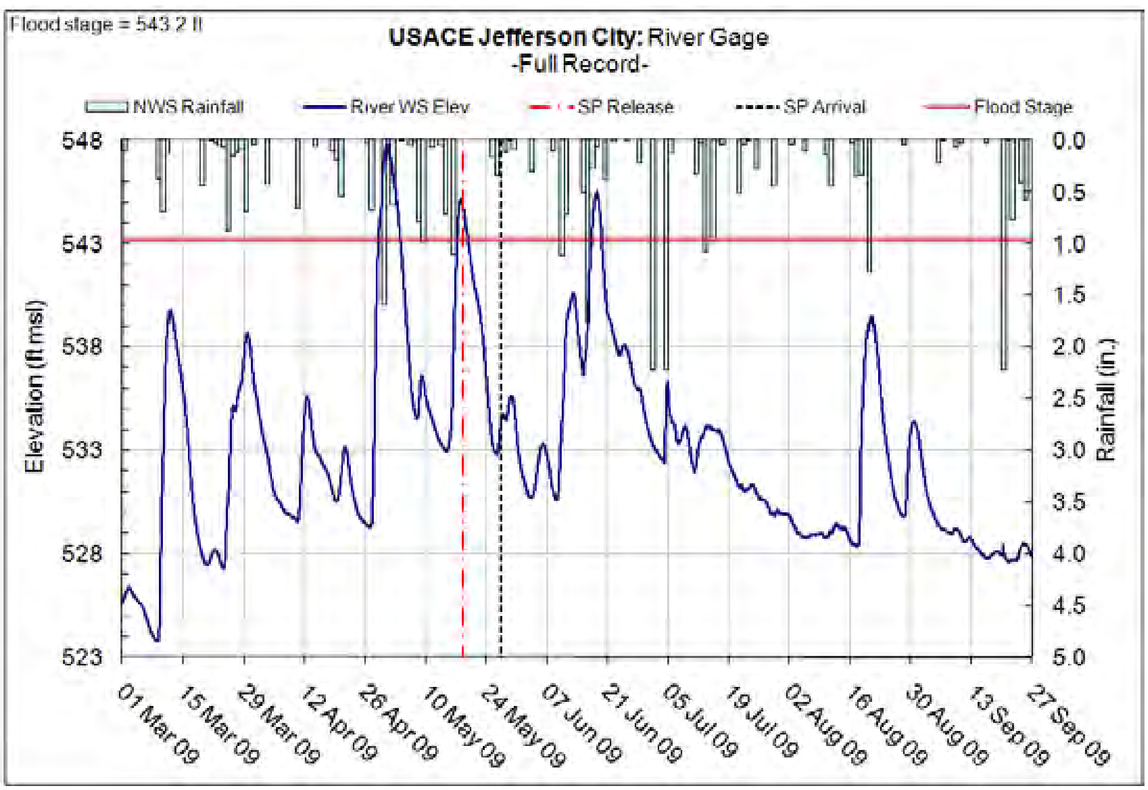

Figure 10.43.3 – Full monitoring record at Jefferson City

10.44 Tebbetts East LD

The supplemental Tebbetts East LD site is located at RM 124.8 on the left side of the St. Aubert Bend in Callaway County, MO (Figure 10.44.1). In 2008 the Tebbetts levee was blown out by high inflows from the Osage River immediately upstream. The levee was reconstructed in 2009 (Figure 10.44.2) and was still in the processes of being repaired in March 2009 when supplemental gages were installed by the USGS. The levee blowout was repaired before the high water period. The drainage structure at the site is a single 12-in. CMP culvert through the main levee with an open inlet and a flap-gated outlet (Figure 10.44.2). The site has no pump and the outlet of the structure drains into the Middle River lowlands. The surveyed crest elevation of the levee is 535.29 ft.

One data logger was installed at the site on the LS interior of the levee. The data logger was installed at a higher elevation on the levee (around 527.5 ft) than the inlet invert of the CMP (525.26 ft) because the USGS could not install it lower and closer to the inlet ditch without encroaching into the construction area at the time the levee was being reconstructed in 2009. No RS data logger was installed at the site. The riverside elevations shown in the figures were adopted from the Howard Levee RS data logger downstream and adjusted to the site elevation by increasing the readings by 0.33 ft based on the differences in the CRP elevations (typical moderate flow profile) between the RS gage and the site.

Field elevations were surveyed in 2009. The typical field elevation within the levee is 527.2 ft. All elevations are in the NAVD 88 datum. This site was installed to document the effects of the created spring rise on a newly reconstructed levee. Flows were estimated at the site by lagging the flow record of the Osage River near St. Thomas to the Missouri River, adding it to the lagged flow record of USGS Boonville, and then lagging the resulting record to the site.

Results and Discussion

- Table 10.44.1 summarizes the results for the May 2009 created spring rise, and the Missouri River flows estimated to reach the outlet and inlet of the site's drainage structure.
- Table 10.44.2 summarizes the socioeconomic impacts produced by the natural spring rises at the site in May 2009.
- Figure 10.44.4 shows the spring pulse release on May 18 and its arrival time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise created by the spring pulse could not be identified from other effects at this site. Based on the attenuation analysis, the spring pulse accounts for 0 kcfs of the total 136-kcfs Missouri-River flow at this river mile, or 0% of the total flow.
- Figure 10.44.5 shows the full period of the monitoring record with the time of the May spring pulse's release and its travel time to the site shown.
- Figure 10.44.6 shows the full period of the monitoring record with the inlet- and the outlet-invert elevations of the drainage structure.
- Figure 10.44.7 shows the 2009 surveyed LS field elevation. The surveyed LS field (527.2 ft) is at a lower elevation than the data logger (around 527.5 ft) because the levee was under reconstruction during the supplemental gage installation and the USGS could not install it lower and closer to the inlet without encroaching into the construction area. Some ponding occurred behind the levee in the location of the data logger during the late April to early July high-flows in 2009 due to interior drainage. The fluctuation in the LS water surface elevation is an indication of that interior drainage. High flows in the Missouri River may have restricted drainage in 2009, but due to the disconnect between

the location of the CMP inlet and the location of the installed data-logger, it cannot be concluded that high natural flows socioeconomic impacted this site in 2009.

- Figure 10.44.8 shows the levee crest elevation (535.29 ft). The levee was not overtopped during the period of record.
- Figure 10.44.9 shows an estimate of the outlet-invert flow threshold. The Missouri River has to be over an estimated 174 kcfs to reach the outlet invert of this site.
- Figure 10.44.10 shows an estimate of the inlet-invert flow threshold. The Missouri River has to be over an estimated 179 kcfs to reach the inlet invert of this site.

Conclusions

No socioeconomic impacts were produced the May 2009 created spring rise as it had fully attenuated by this site. The levee was not overtopped during the monitoring period by either the Missouri River or the Middle River. The levee blowout was repaired before the high water period. Socioeconomic impacts due to natural spring rises were inconclusive because the location of the LS data logger was installed too far from the inlet invert of the site due to construction at the site at the time of the installation. Ponding did occur behind the levee but it is not conclusive if this ponding was affected by high flows in the Missouri River in 2009. Based on the attenuation analysis, the spring pulse accounts for 0 kcfs of the total 136 kcfs Missouri River flow at this river mile, or 0% of the total flow.

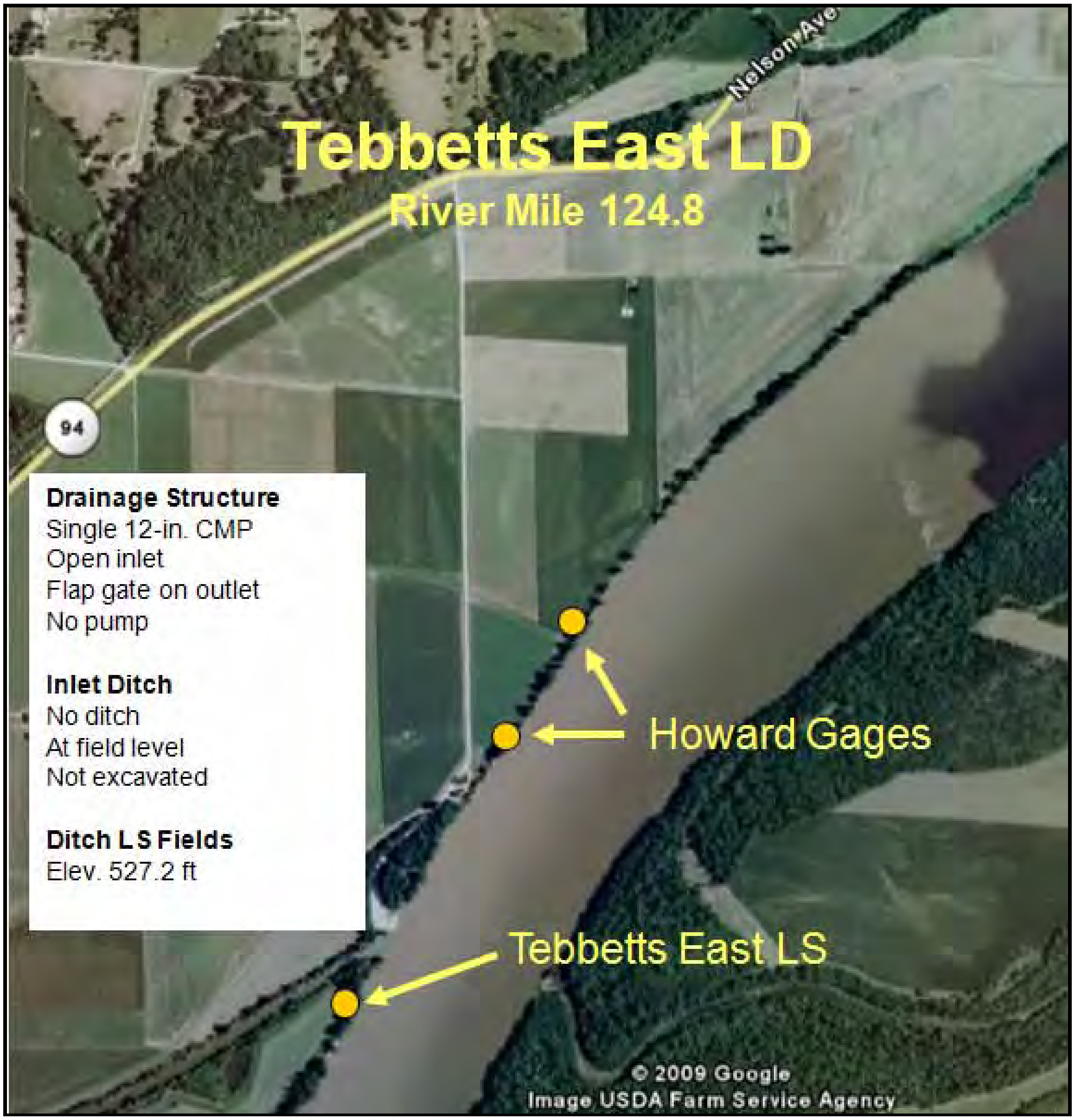

Figure 10.44.1 – Tebbetts East LD location

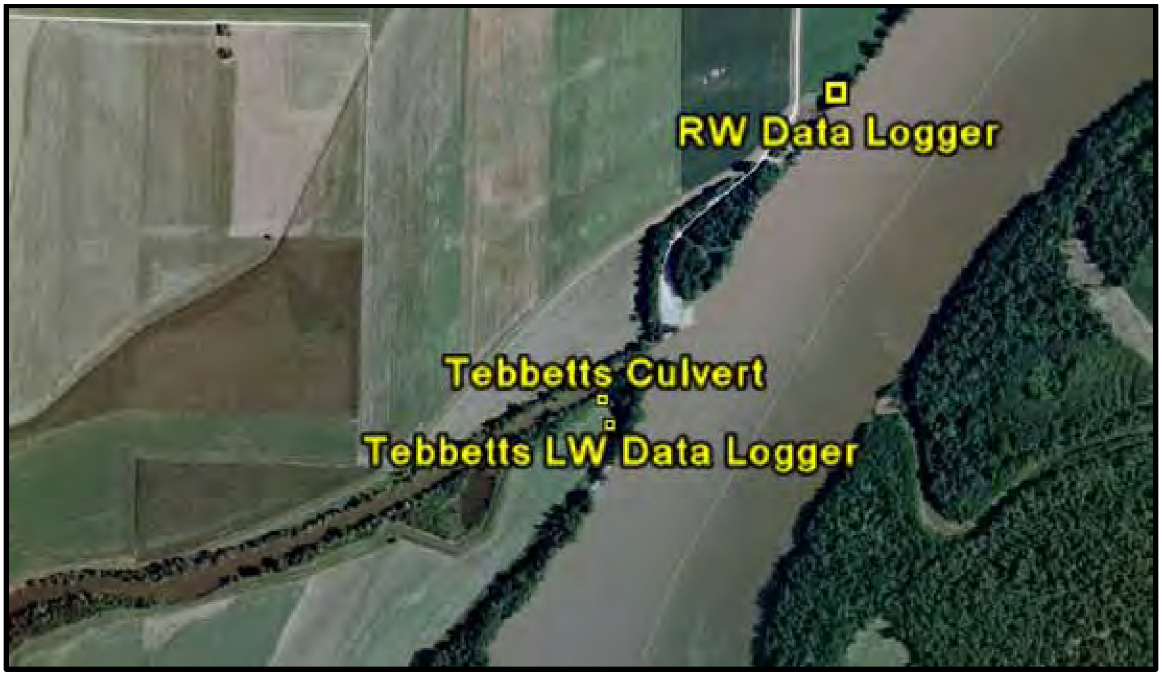

Figure 10.44.2 –Tebbetts East LD culvert and LW data logger locations

Figure 10.44.2 – Tebbets East LD site. 2008 levee blowout from back channel of Missouri River before repairs (left). Repaired levee blowout but interior washout still present in August 2009 (right).

Figure 10.44.3 – Tebbets East LD main levee drainage structure. Inlet to 12-in. culvert through main levee on landside (top left). Outlet of 12-in. culvert through main levee; drains to creek tributary to the Missouri River along back side of levee (top right). Inlet culvert of levee and LS of site; inlet obscured by bushes (bottom left). Culvert inlet location in comparison to LS data logger (bottom right).

Table 10.44.1 – Tebbetts East LD results

Spring Pulse from Gavins Point Dam	*May-09*	*Mar-08*
Created spring rise, ft	0	-
Estimated created spring rise flow, kcfs	0	-
Estimated MR flow at site, kcfs	136	-
% of MR flow	0	-
Outlet-flow Threshold	*May-09*	*Mar-08*
Elev, ft	525.14	-
Estimated MR flow at site, kcfs	174	-
Inlet-flow threshold	*May-09*	*Mar-08*
Elev, ft	525.26	-
Estimated MR flow at site, kcfs	179	-

Table 10.44.2 – Tebbetts East LD NSR socioeconomic impacts

2009 Natural Spring Rise Impacts	*LS Flooding*	*Gate Closure*
Elev, ft	527.2	-
Total impact duration, dy	Inconclusive	Inconclusive
Estimated MR flow at site, kcfs	-	-
Flow at nearest US gage, kcfs	-	-
Nearest US gage	-	-

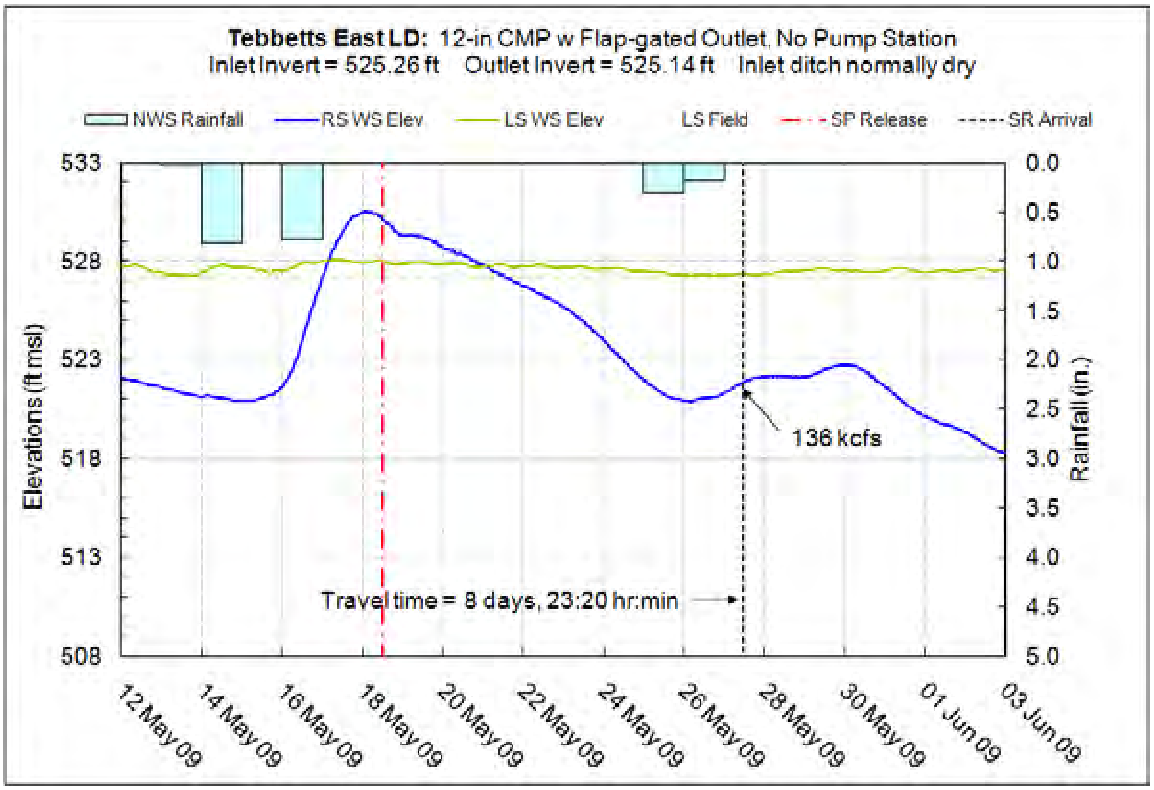

Figure 10.44.4 – Spring rise at Tebbetts East LD

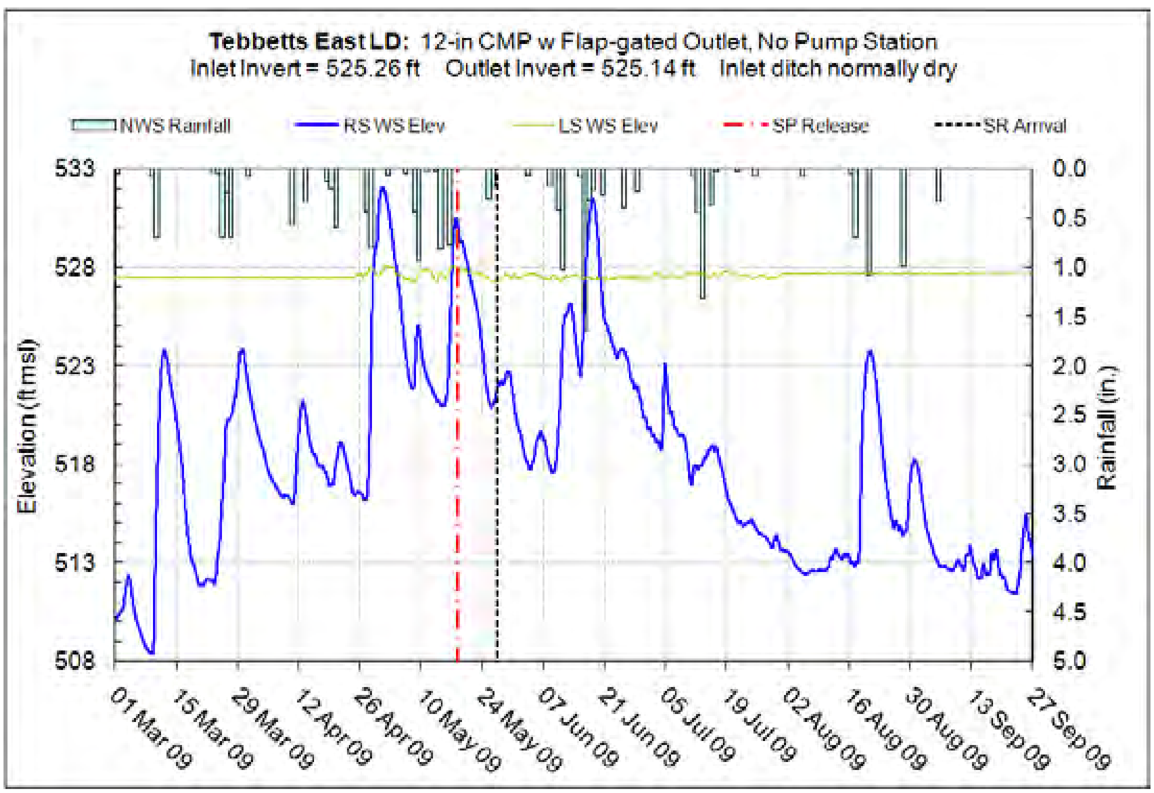

Figure 10.44.5 – Full monitoring record at Tebbetts East LD

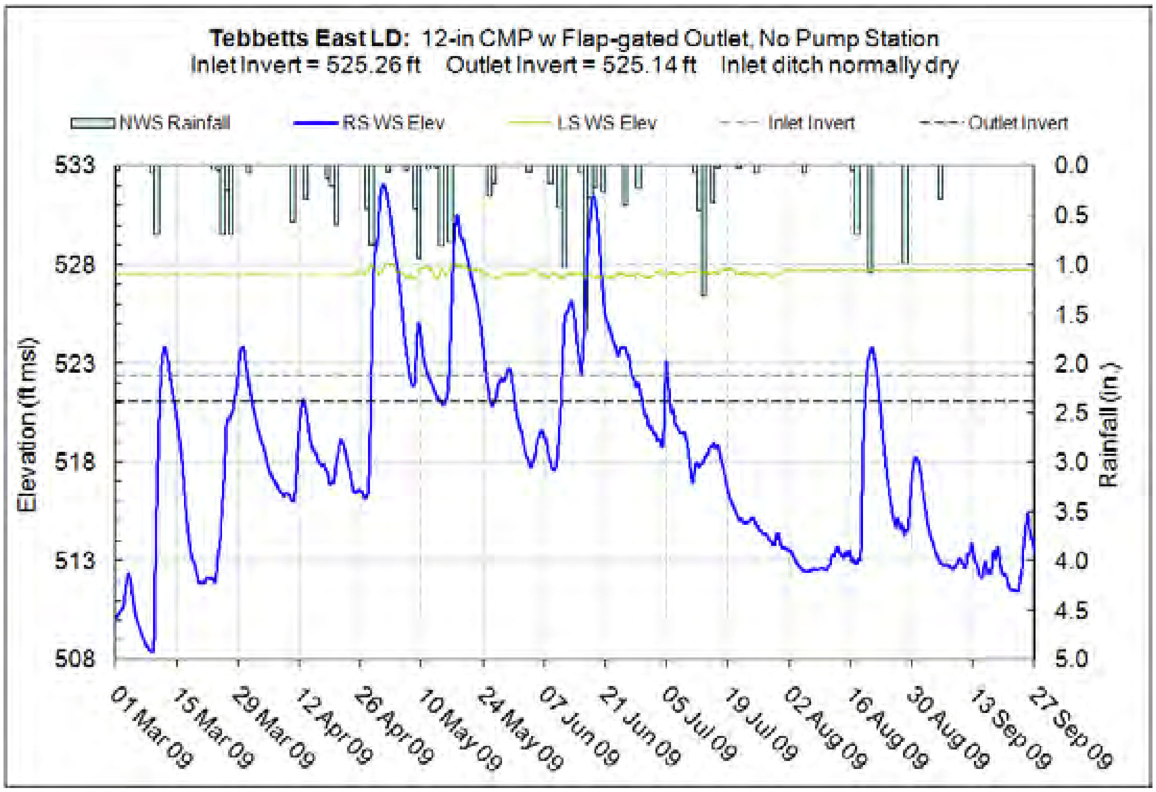

Figure 10.44.6 – Invert elevations, Tebbetts East LD

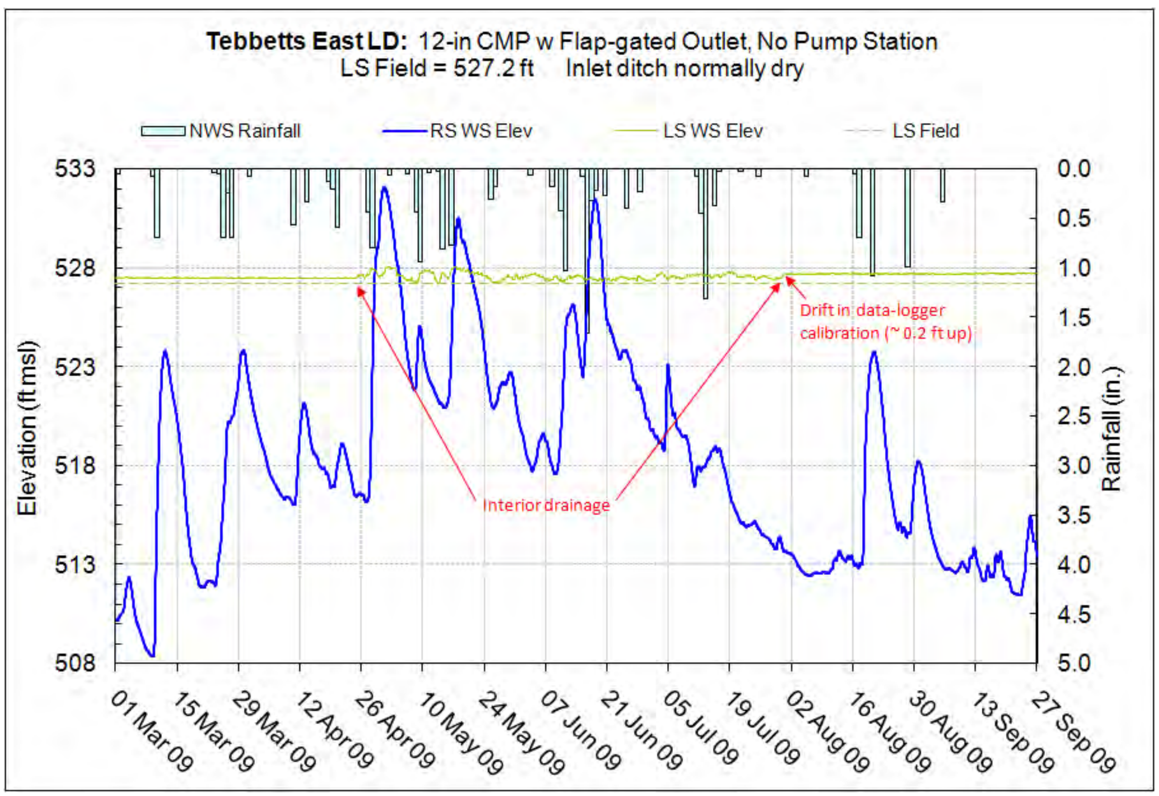

Figure 10.44.7 – Surveyed field elevations, Tebbetts East LD

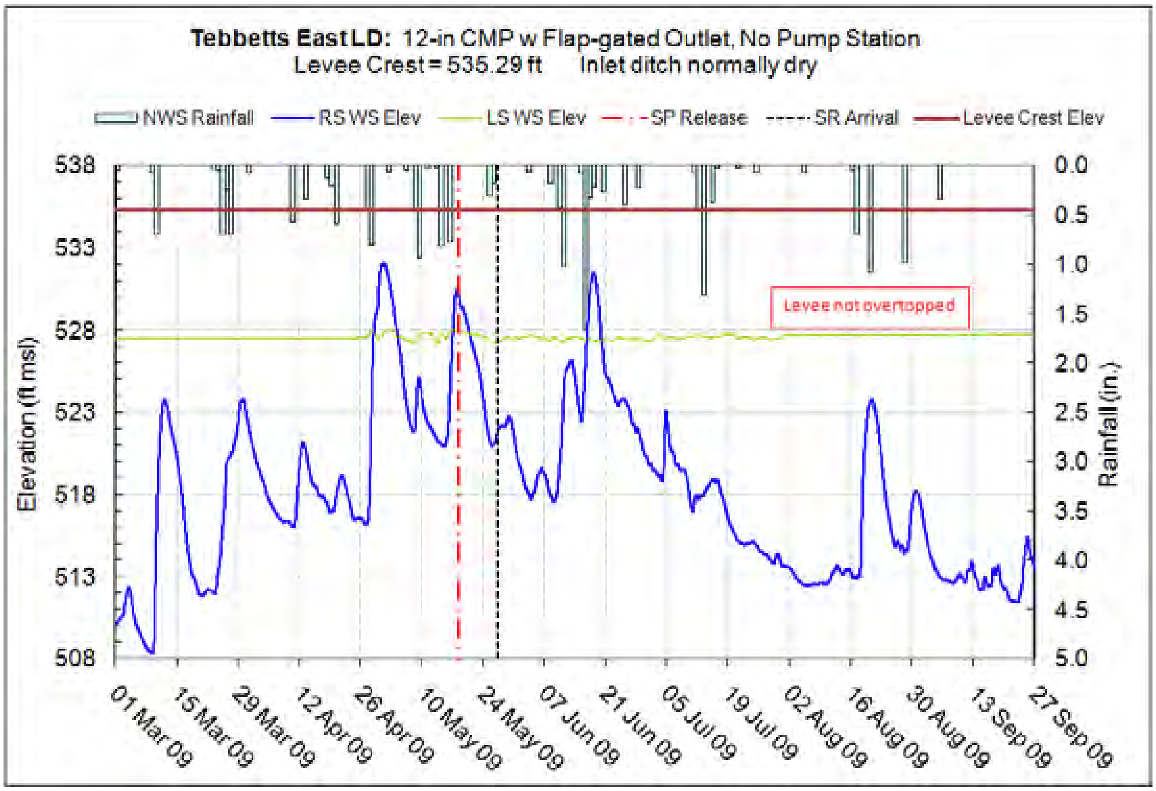

Figure 10.44.8 – Levee crest elevations, Tebbetts East LD

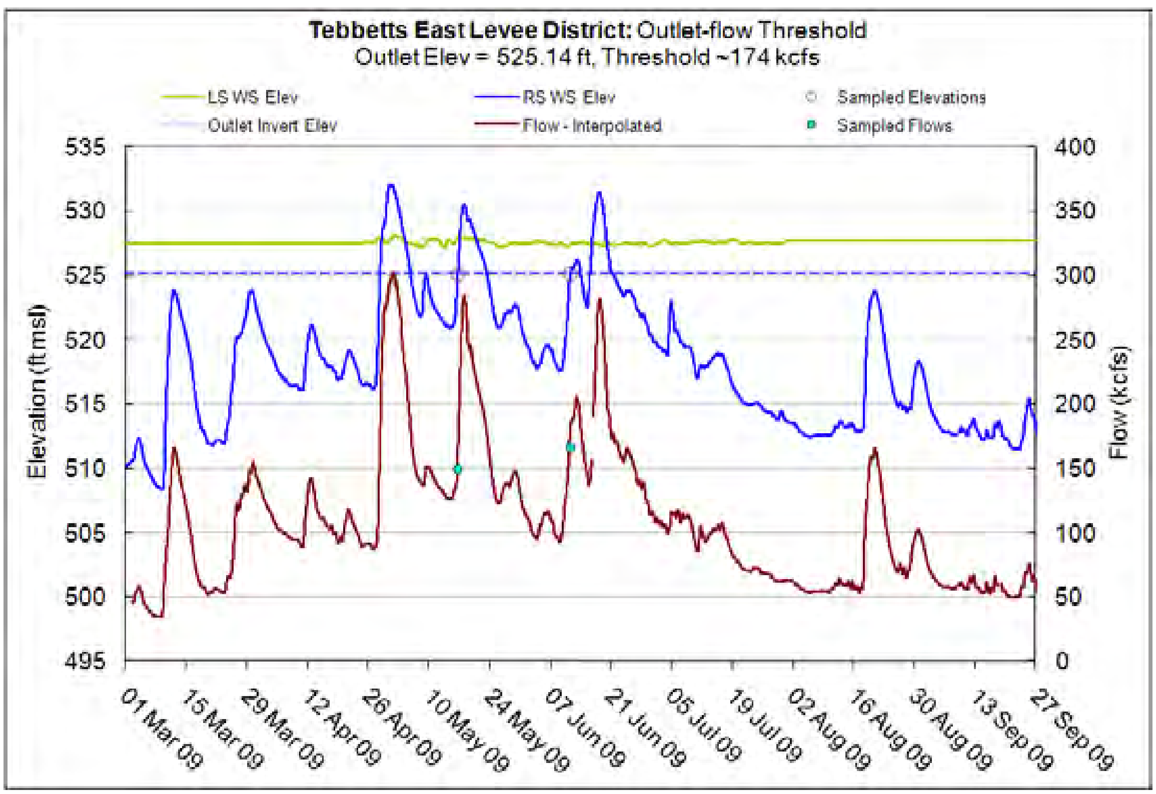

Figure 10.44.9 – Outlet-flow threshold, Tebbetts East LD

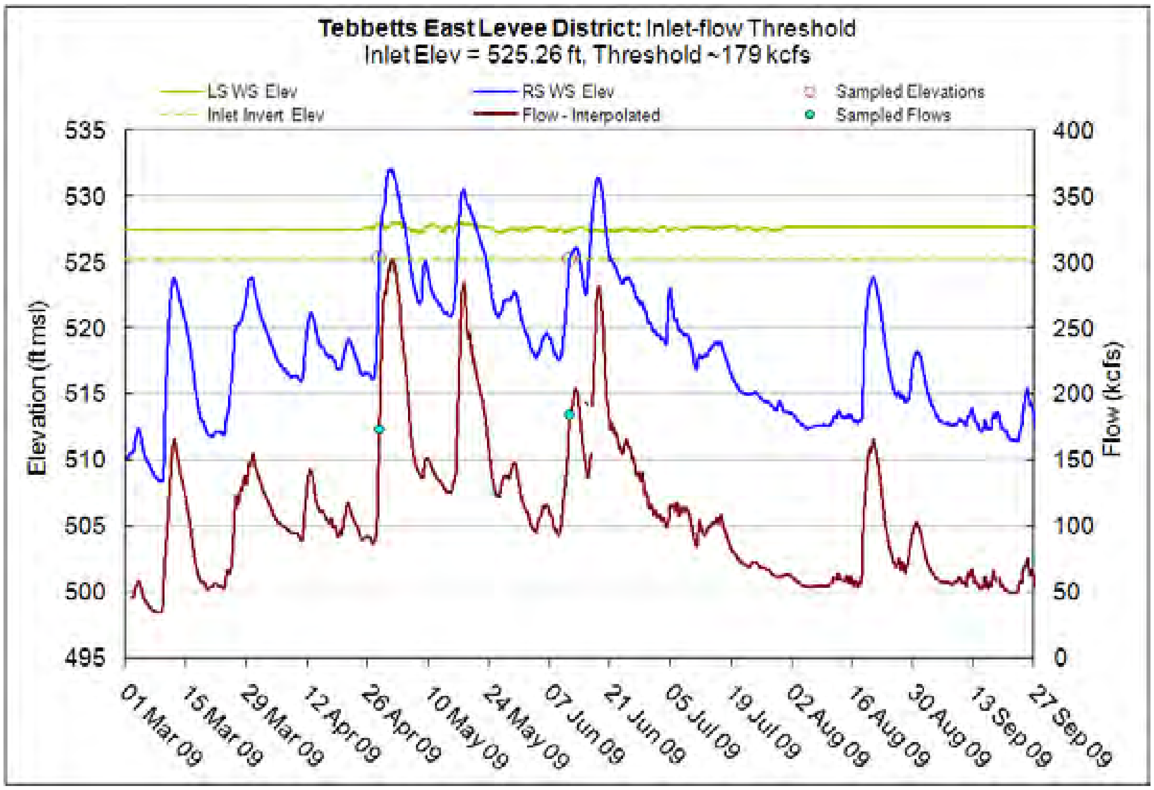

Figure 10.44.10 – Inlet-flow threshold, Tebbetts East LD

10.45 Howard Levee

The supplemental gages at the Howard Levee site (also known as Howard Levee) are located at RM 124.4 and 124.2 on the north bank of the St. Albert Bend of the Missouri River in Callaway County, MO (Figure 10.45.1). The drainage structure at this site is a single 36-in. CMP through Howard Levee about 0.2 mile DS of the intersection of the Howard Levee and Mokane Boat Ramp access road (Figure 10.45.2). The inlet of the CMP is open and the outlet of the CMP has a flap gate. The drainage ditch has no berms and is excavated about 4 ft below the field elevation along an old creek bed. The outlet drains directly to the river and the site does not have a pump. The elevation of the inlet invert is 522.37 ft, the elevation of the outlet invert is 521.07 ft, and the elevation of the crest of the levee over the site is 535.73 ft.

Two data loggers were installed. The LS data logger was installed next to the culvert inlet in the drainage ditch at RM 124.2. The RS data logger was installed on the river bank 0.2 miles upstream (RM 124.4) of the of the drainage structure outlet. The water elevations at the RS gage were adjusted 0.16 ft down based on the differences in CRP elevations (typical moderate flow profile).

Field elevations were surveyed in 2009. The fields on either side of the inlet ditch are about the same elevation. The field elevation surveyed was 528.4 ft. All elevations are in the NAVD 88 datum. Flows were estimated at the site by lagging the flow record of the Osage River near St. Thomas to the Missouri River, adding it to the lagged flow record of USGS Boonville, and then lagging the resulting record to the site.

Results and Discussion

§ Table 10.45.1 summarizes the results for the May 2009 created spring rise, and the Missouri River flows estimated to reach the outlet and inlet of the site's drainage structure. Table 10.45.2 summarizes the socioeconomic impacts produced by the natural spring rises at the site in May 2009.

§ Figure 10.45.3 shows the spring pulse release on May 18 and its travel time to the site. This figure illustrates there were no socioeconomic impacts due to the 2009 created spring rise. The rise created by the May spring pulse was zero feet at this site. Based on the attenuation analysis, the spring pulse accounts for 0 kcfs of the total 137-kcfs Missouri-River flow at this river mile, or 0% of the total peak flow.

§ Figure 10.45.4 shows the full period of the monitoring record with the time of the May spring pulse's release and its travel time at the site shown.

§ Figure 10.45.5 shows the full period of the monitoring record with the inlet- and outlet-invert elevation of the drainage structure.

§ Figure 10.45.6 shows the 2009 surveyed field elevation for the LS field.

§ Figure 10.45.7 shows the estimated socioeconomic impacts from natural spring rises at the site. Gate closures appear to have occurred three times in the record.

§ Figure 10.45.8 shows the determination of impact thresholds for the possible gate closures. Estimated flows in the Missouri River at RM 124.4 at the time of the accumulation were around 216 kcfs. The total duration of the accumulation created by gate closures was 12.8 days.

§ Figure 10.45.9 shows the estimation of the outlet-invert flow threshold. The estimated threshold flow in the Missouri River required to reach the outlet-invert elevation of the site is about 135 kcfs.

§ Figure 10.45.10 shows the estimation of the inlet-invert flow threshold. The estimated threshold flow in the Missouri River required to reach the inlet-invert elevation of the site is about 143 kcfs.

Conclusions

No socioeconomic impacts were caused by the created spring rise in May 2009. Based on the attenuation analysis, the spring pulse accounts for 0 kcfs of the total 137 kcfs Missouri-River flow at this river mile, or 0% of the total flow. The accumulation of water in LS drainage ditches was the impact identified from natural spring rises. Accumulation created by gate closures occurred three times in the record. The total duration of the accumulation was 12.8 days. The average duration of accumulation was 4.3 days.

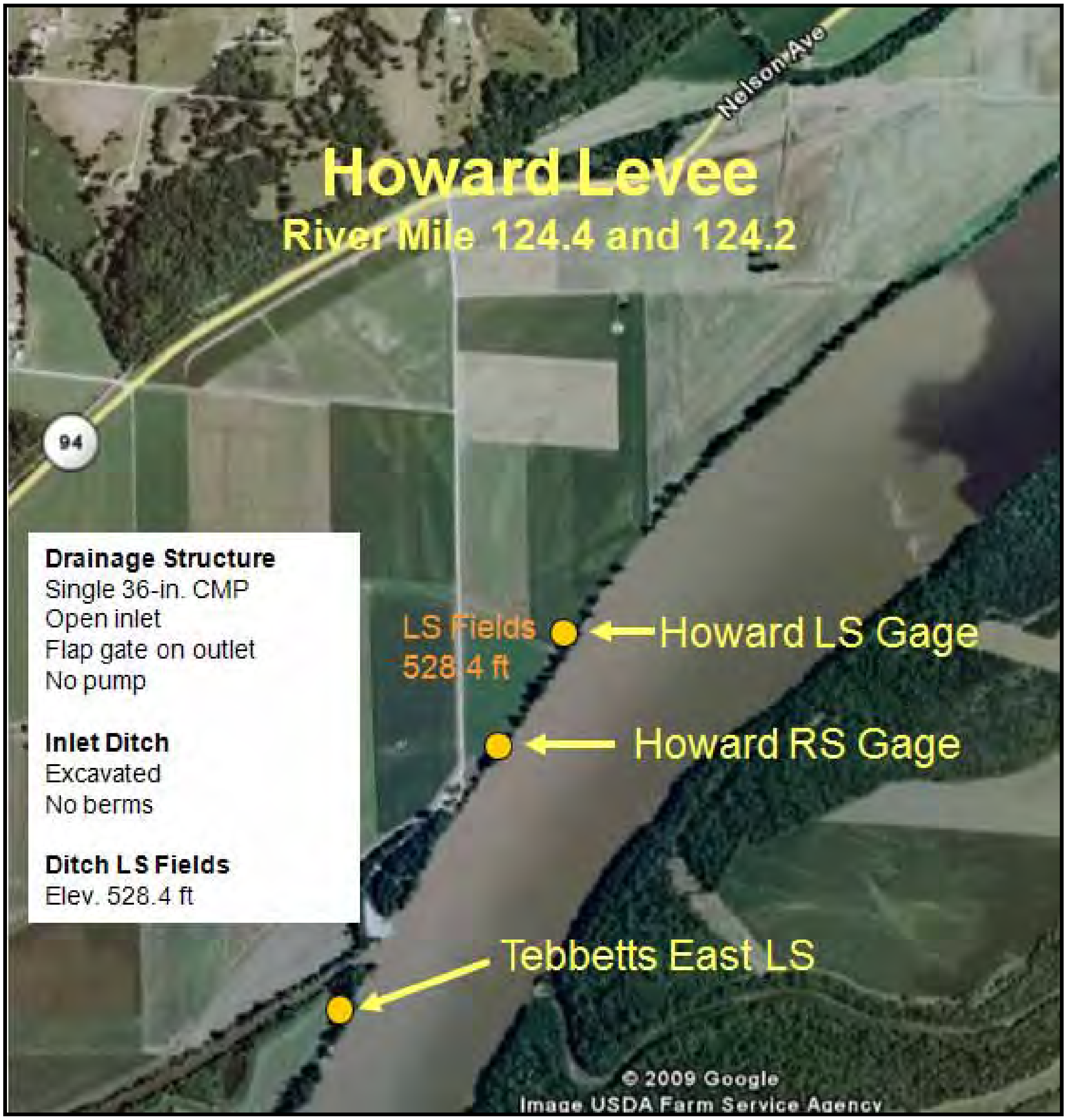

Figure 10.45.1 – Howard Levee location

Figure 10.45.2 – Howard Levee site and gages. Inlet of 36-in. culvert and data logger pipe (top left). Outlet of 36-in. culvert at river (top right). River data logger near boat ramp (bottom left). Landside data logger and fields (bottom right).

Table 10.45.1 – Howard Levee results

Spring Pulse from Gavins Point Dam	May-09	Mar-08
Created spring rise, ft	0	-
Estimated created spring rise flow, kcfs	0	-
Estimated MR flow at site, kcfs	137	-
% of MR flow	0.0	-

Outlet-flow Threshold	May-09	Mar-08
Elev, ft	521.07	-
Estimated MR flow at site, kcfs	135	-

Inlet-flow threshold	May-09	Mar-08
Elev, ft	522.37	-
Estimated MR flow at site, kcfs	143	-

Table 10.45.2 – Howard Levee NSR socioeconomic impacts

2009 Natural Spring Rise Impacts	LS Flooding	Gate Closure
Elev, ft	528.4	525.5
Impact duration, dy	no flooding	2.6 – 5.6
Estimated MR flow at site, kcfs	-	216

2008 Natural Spring Rise Impacts

Not monitored in 2008.

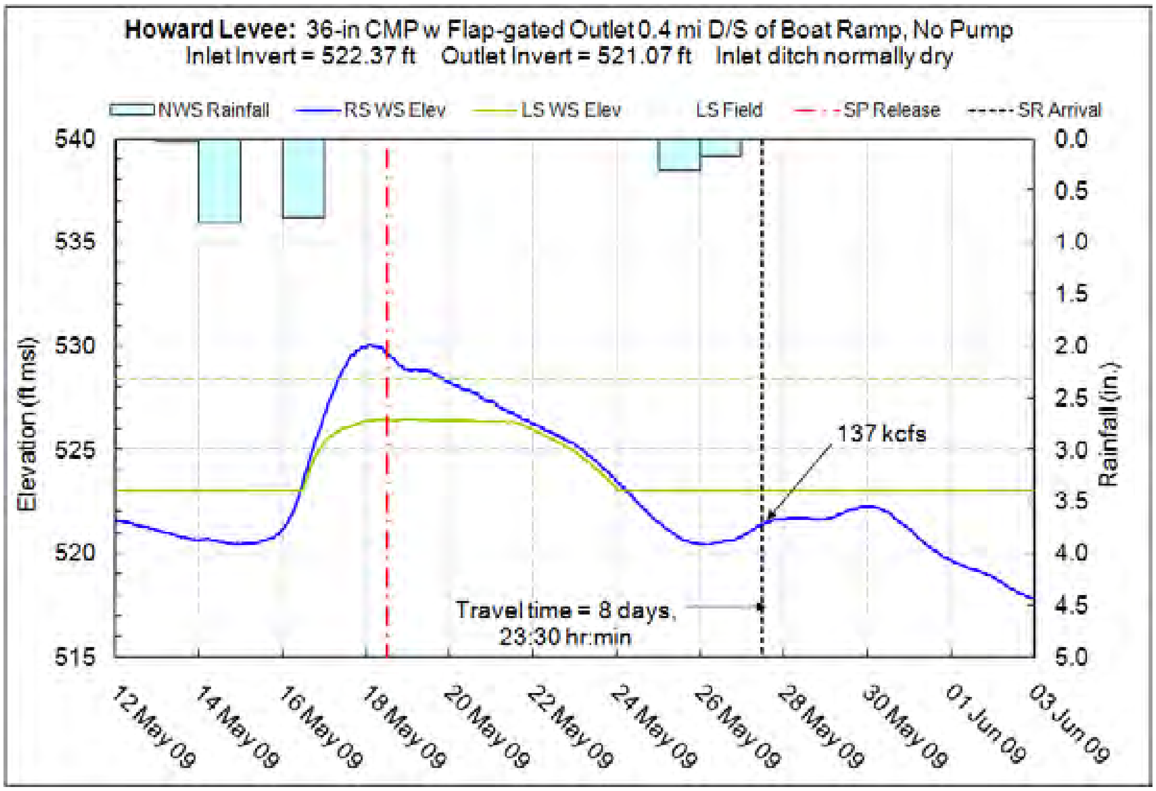

Figure 10.45.3 – Spring rise at Howard Levee

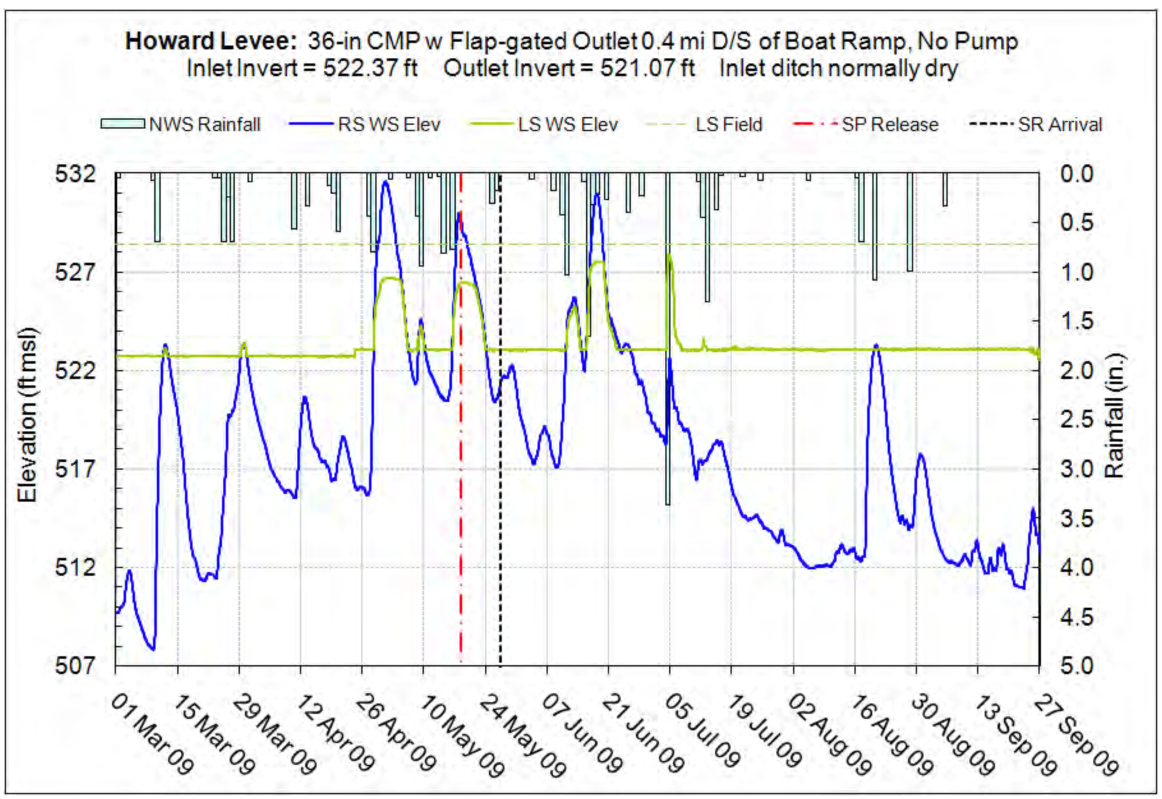

Figure 10.45.4 – Full monitoring record at Howard Levee

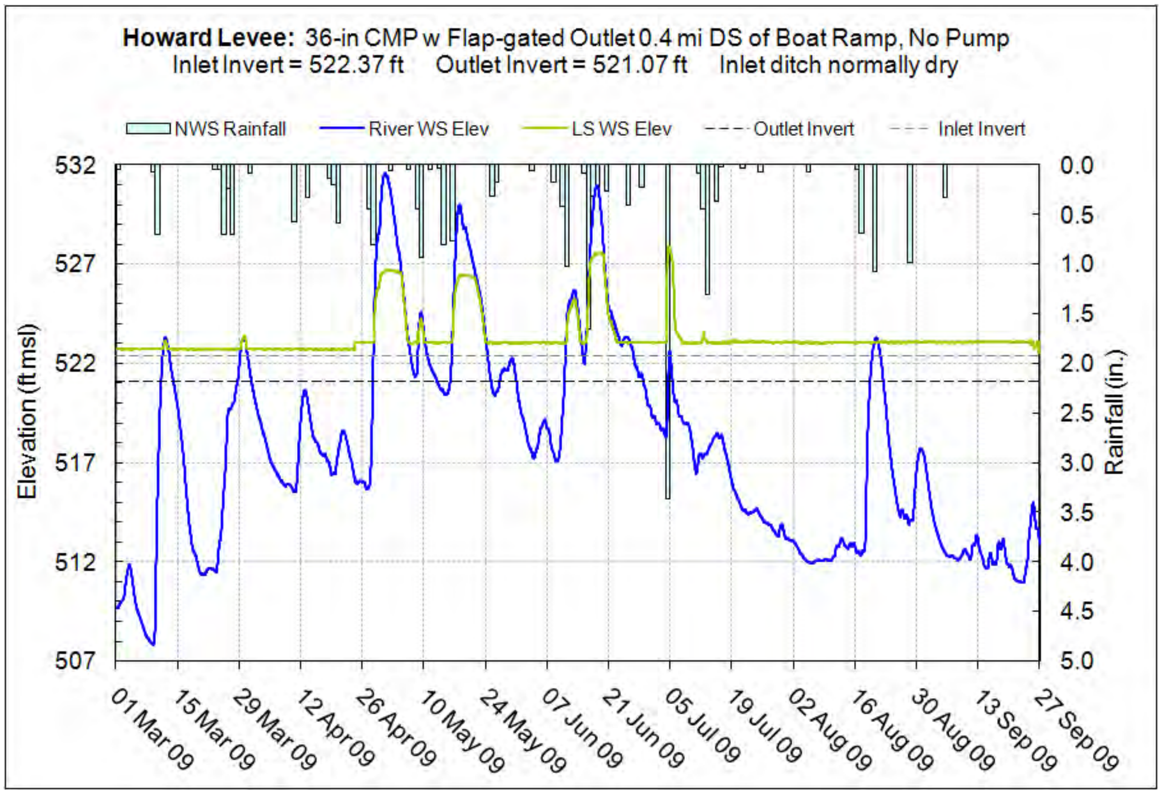

Figure 10.45.5 – Invert elevations, Howard Levee

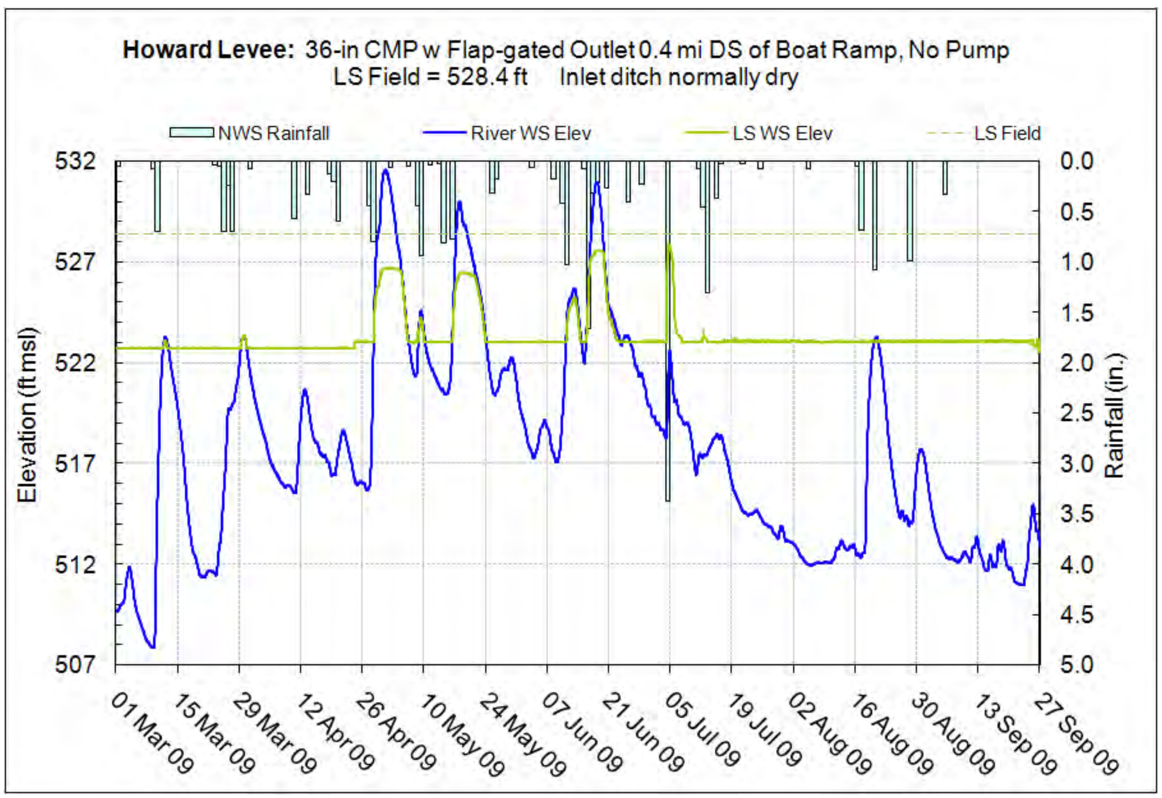

Figure 10.45.6 – Surveyed field elevation, Howard Levee

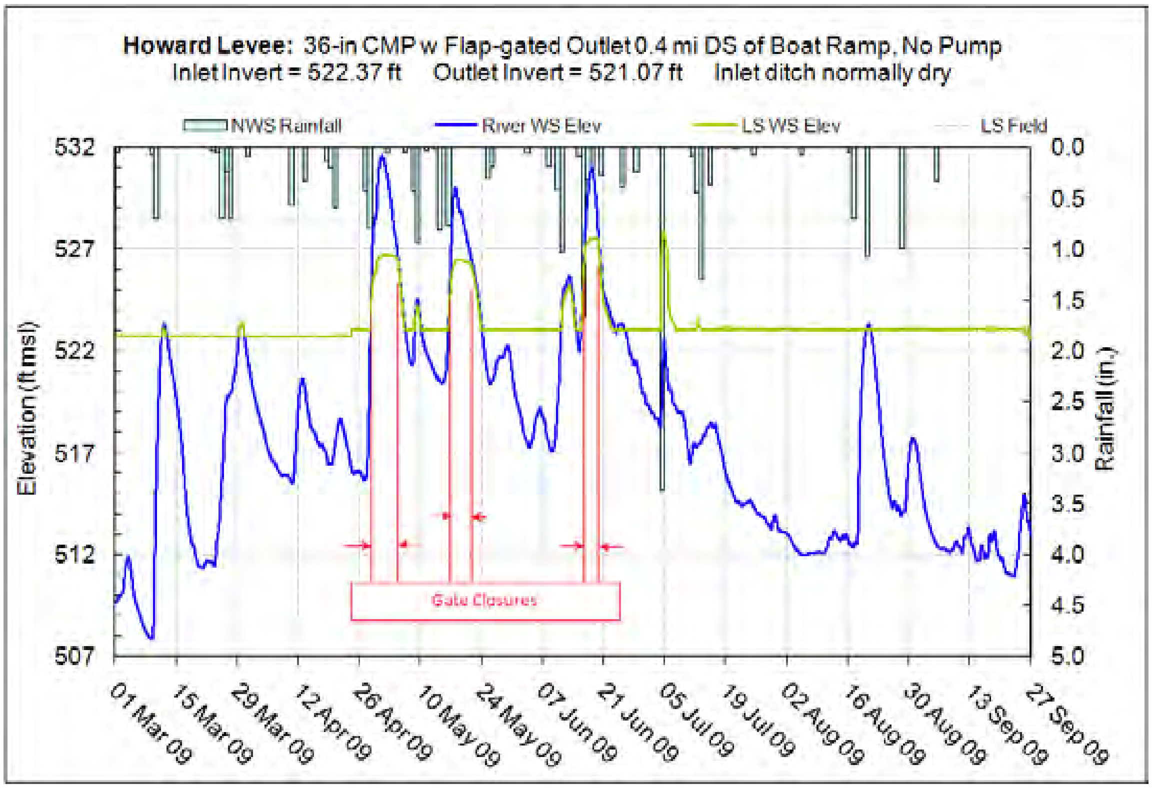

Figure 10.45.7 – NSR impacts, Howard Levee

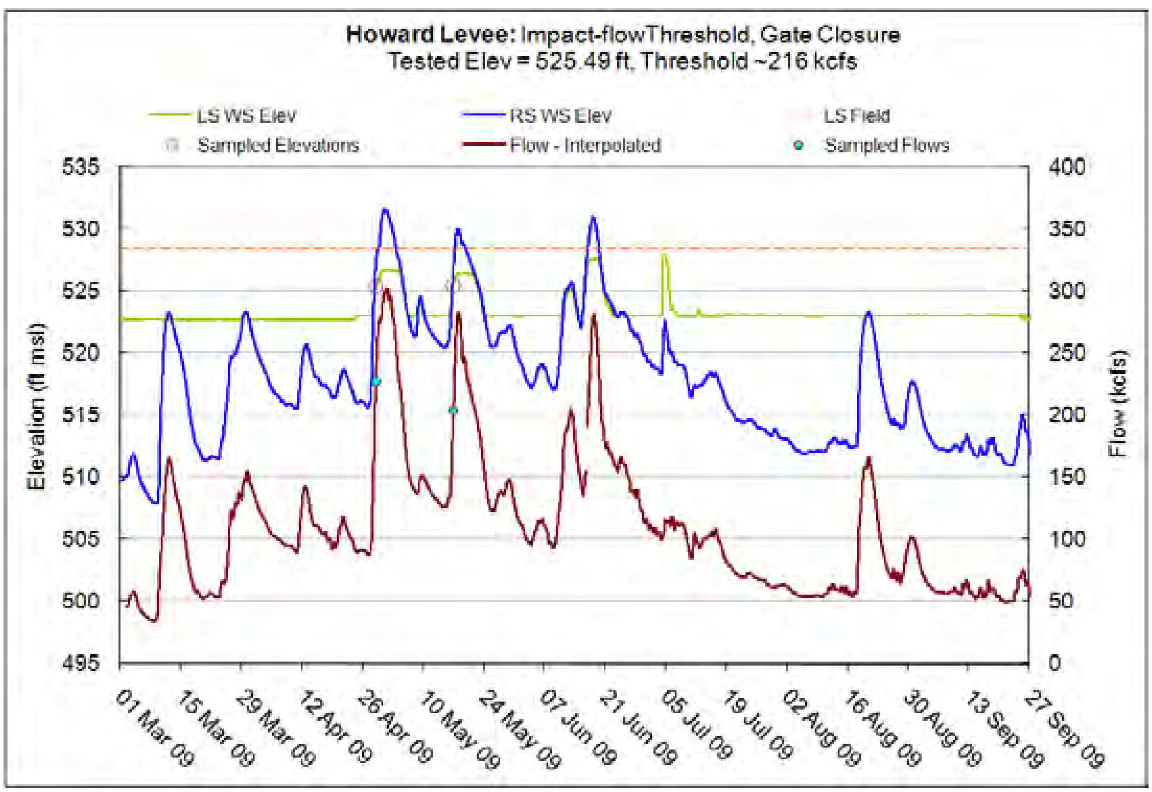

Figure 10.45.8 – Impact-flow threshold (gate closure), Howard Levee

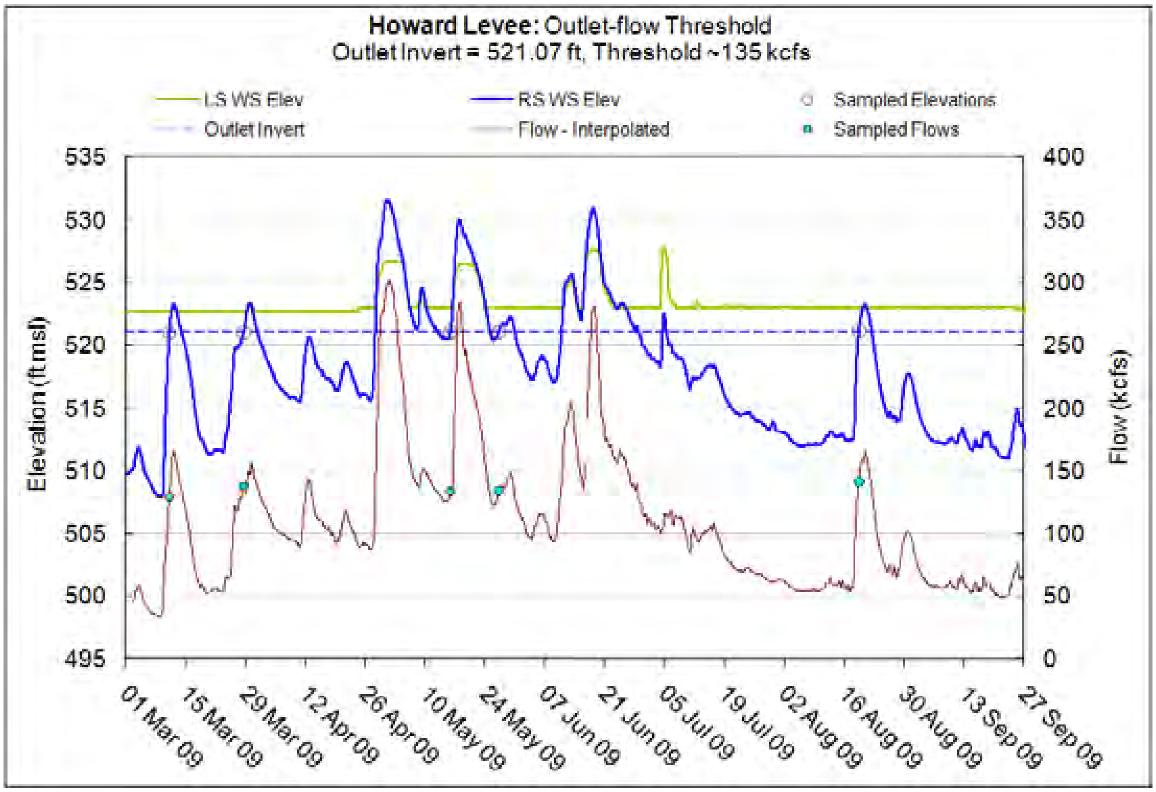

Figure 10.45.9 – Outlet-flow threshold, Howard Levee

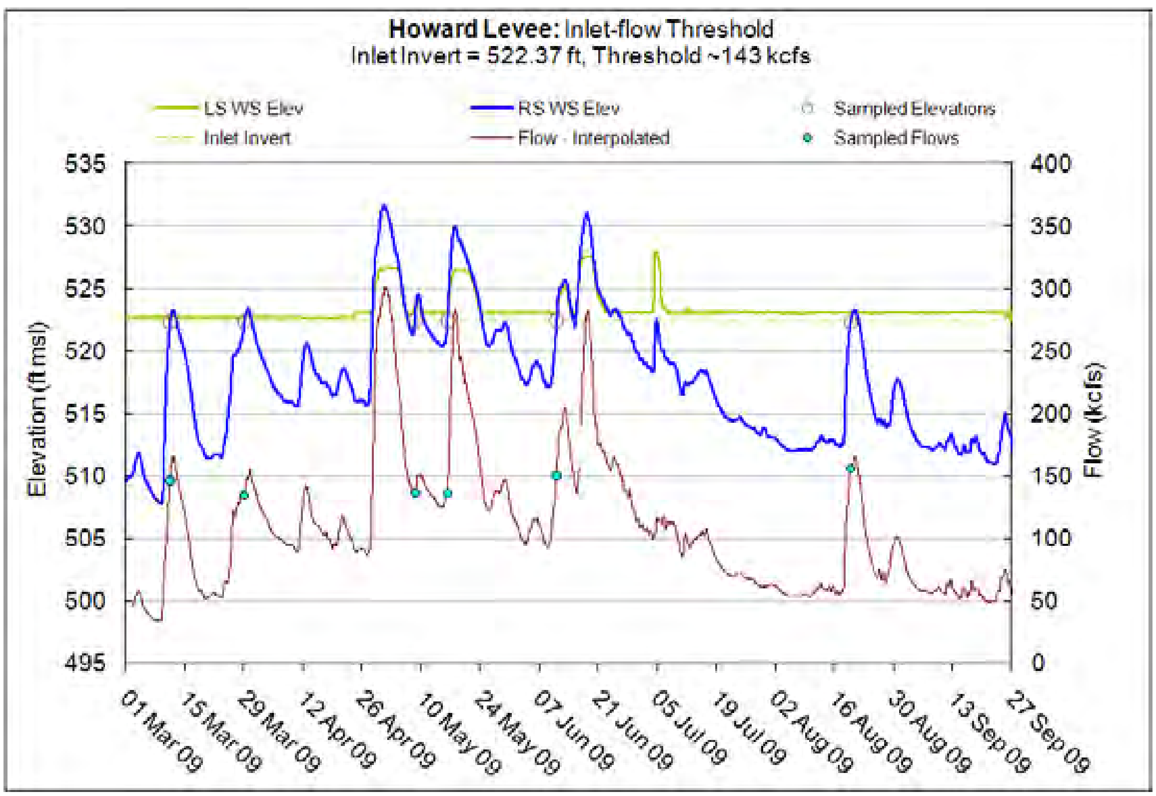

Figure 10.45.10 – Inlet-flow threshold, Howard Levee

10.46 USGS Hermann

The USGS Missouri River Hermann gage is located at Hermann, MO on the Market Street bridge on the right bank of the Missouri River at river mile 97.9 (Figure 10.45.1). Flood stage was exceeded four times by natural spring rises at the USGS Missouri River gage in 2009. All flood durations were less than one week.

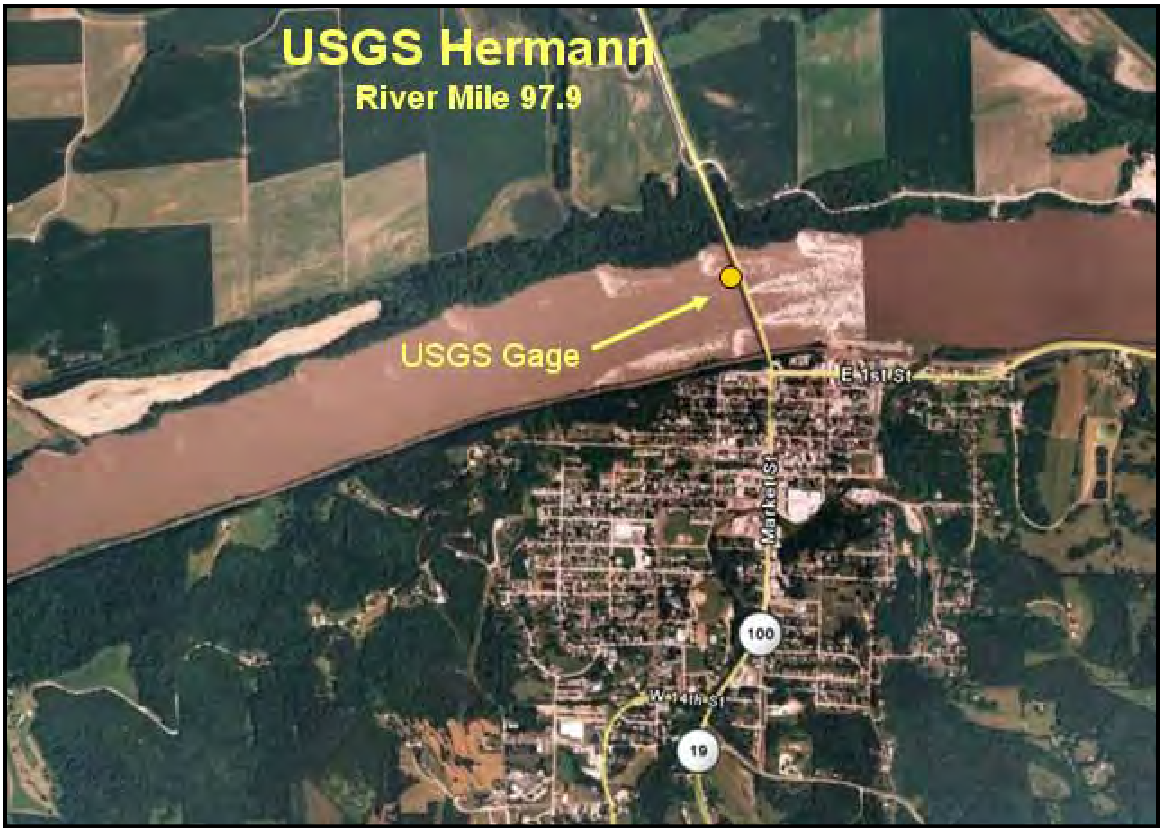

Figure 10.46.1 – USGS Hermann location

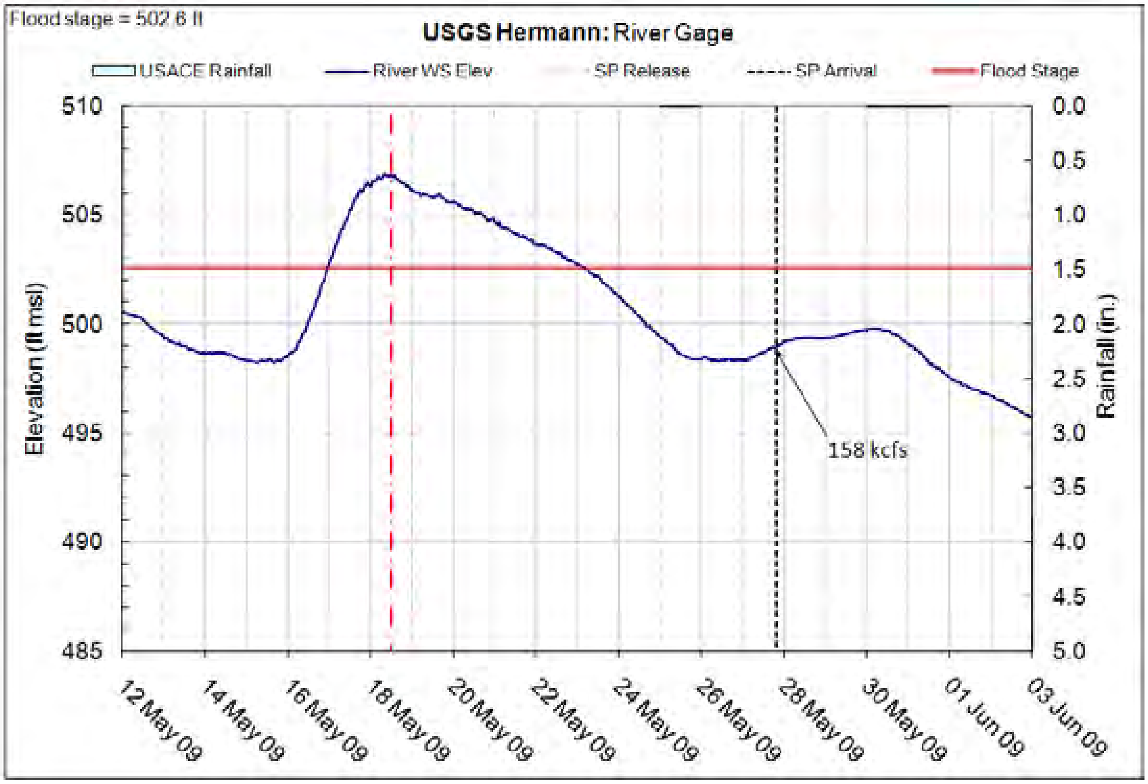

Figure 10.46.2 – Spring rise at USGS Hermann

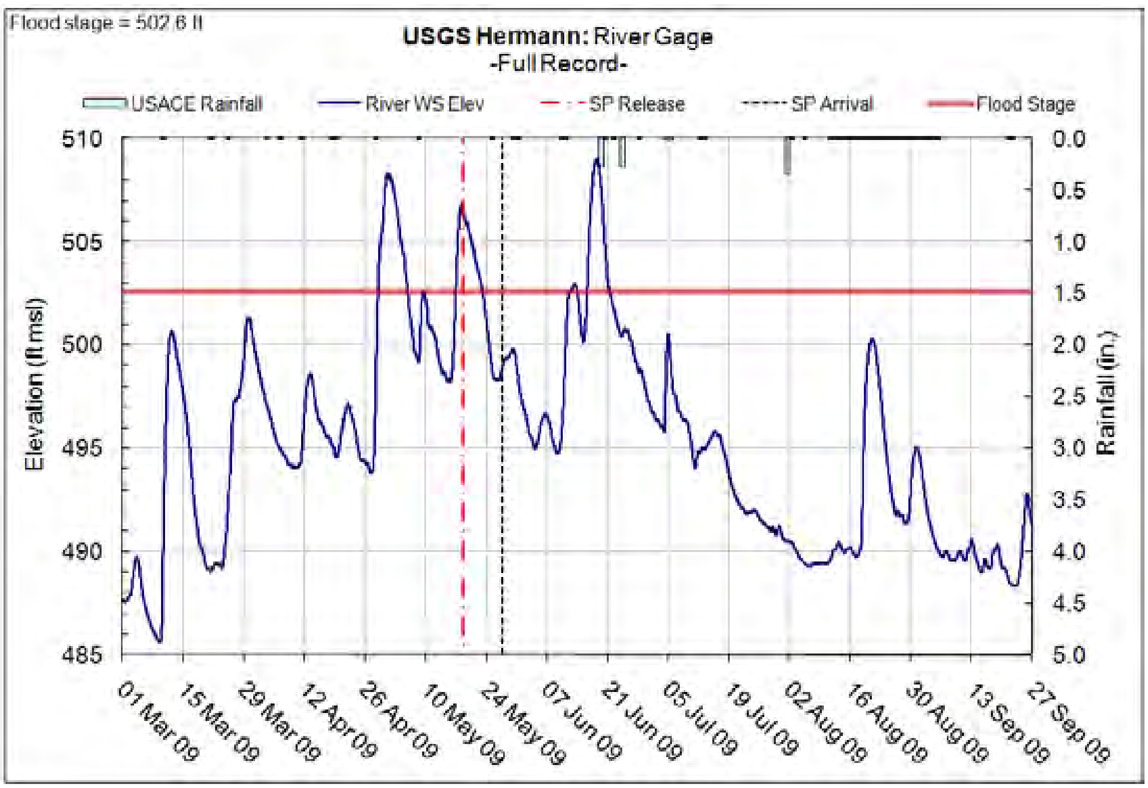

Figure 10.46.3 – Full monitoring record at USGS Hermann

11.0 Impact Summary

No sites were impacted socioeconomically by the created spring pulse released from Gavins Point Dam for the benefit of the endangered pallid sturgeon. However, high natural spring rises did result in socioeconomic impacts. Socioeconomic impacts included gate closures, pumping, and overbank flooding. Table 11.0.1 lists the sites monitored in 2008 and 2009 by river mile, the years they were monitored, and their structures.

Table 11.0.1 – Site Inventory (2006, 2008 and 2009)

Site	RM	Gage Type	Monitored	Pump	Flap Gate	Manual Gate
Ponca State Park	753.4	River	2008	N	N	N
Harts Lighthouse Marina	699.5	River	2006 & 2008	N	N	N
Pelican Point	672.7	River	2008 & 2009	N	N	N
County Line Ditch	659	Ditch	2006, 2008 & 2009	N	N	N
California Bend	650.6	Levee	2006, 2008 & 2009	N	Y	N
McIntosh Levee	637.1	Levee	2006, 2008 & 2009	N	Y	N
La Platte	596.7	River	2008 & 2009	N	N	N
Lake Wa Con Da	577.5	River	2008 & 2009	N	N	N
L-575 Structure No. 23	545.9	Levee	2006, 2008 & 2009	Y	Y	Y
R-562/Peru	542.1	River	2008	N	N	N
L-536 Structure No. 8	521.5	Levee	2006, 2008 & 2009	Y	N	Y
Holt County LD No. 9	490.8	Levee	2006 & 2009	N	Y	N
R-500	480.2	Levee	2009	Y	N	Y
L-497 Main Outfall	477.1	Levee	2006, 2008 & 2009	Y	N	Y
L-488	472.8	Levee	2009	Y	N	Y
L-448/443	428.4	Levee	2009	Y	N	Y
R-440 Main Outfall	424.9	Levee	2008	Y	N	Y
L-408 Main Outfall	391.9	Levee	2008 & 2009	N	Y	Y
MO Valley DLD	328.7	Levee	2009	N	Y	Y
MO Valley DLD No.1	326.2	Levee	2006 & 2008	N	Y	N
Cole Lake DD No. 2	277.1	Levee	2006 & 2008	Y	Y	Y
Brunswick Terminal	256.3	River	2009	N	N	N
Dewitt DLD	255.3	Levee	2009	N	Y	N
Miami LD No. 1	252.1	Levee	2009	N	Y	N
Brunswick LD	250.3	Levee	2009	Y	Y	N
L-246 Palmer Creek MD	241.8	Levee	2006, 2008 & 2009	N	Y	Y
L-246 Palmer Creek SD	241.8	Side Ditch	2009	N	Y	N
L-246 Dalton Ditch MD	239.4	Levee	2009	Y*	Y	Y
L-246 Dalton Ditch SD	239.4	Side Ditch	2009	Y*	Y	N
Howard County LD No. 6	221.2	Levee	2006 & 2008	N	Y	N
Capital View DD	141.4	Levee	2006 & 2008	N	Y	N
Tebbetts East LD	124.8	Levee	2009	N	Y	N
Howard Levee	124.4	Levee	2009	N	Y	N
Tri-County LD Sect. 1	99.6	Levee	2006 & 2008	N	Y	N

*Site has movable pump

11.1 Created Spring Pulse Socioeconomic Impacts and Rises

The created spring pulse created no socioeconomic impacts in May 2009. Table 11.1.1 summarizes the created spring rise in terms of flow and compares it with the estimated Missouri-River flow at that river mile. The created spring rise flows were calculated from the attenuation equations determined in Section 9. Missouri River flows were either referenced from automatic Missouri River gages or interpolated from automatic gages based on river mile. See Section 8 for details on flow estimation.

Table 11.1.2 summarizes the observed created spring rises at each monitoring site for May 2009, March 2008, and May 2006. These are the rises that were identified through the navigation travel time and estimated from changes in the monitored stage.

Figure 11.1 shows all the observed created spring rises by river mile. Observed rises are those measured from available stage data. Results for May 2009, March 2008, and May 2006 are shown. The May 2009 and March 2008 results were collected by data loggers or DCPs at hourly time intervals and the effects of rainfall and upstream flows were considered. The May 2006 data were estimated from staff-gage readings at most of the sites during the time of the spring rise and the effects of rainfall and upstream flows were not considered.

Table 11.1.1 – Spring rise flows compared with Missouri River flows, May 2009

Site	RM	Calculated Spring Rise Flow, kcfs[1] 2009	Estimated Missouri River Flow, kcfs[2] 2009	% of Missouri River Flow 2009
Pelican Point	672.7	5.6	34	16
County Line Ditch	659.0	5.4	34	16
California Bend	650.6	5.3	34	16
McIntosh Levee	637.1	5.2	35	15
La Platte	596.7	4.6	35	13
Lake Wa Con Da	577.5	4.4	40	11
L-575 Structure No. 23	545.9	3.9	40	9.8
L-536 Structure No. 8	521.5	3.6	41	8.8
Holt County LD No. 9	490.8	3.2	41	7.8
R-500	480.2	3.1	43	7.2
L-497 Main Outfall	477.1	3.0	43	7.0
L-488	472.8	3.0	44	6.8
L-448/443	428.4	2.4	48	5.0
L-408 Main Outfall	391.9	1.9	53	3.6
MO Valley DLD	328.7	1.0	59	1.7
Brunswick Terminal	256.3	0.1	62	0.2
Dewitt DLD	255.3	0.1	62	0.2
Miami LD No. 1	252.1	0	62	0
Brunswick LD	250.3	0	62	0
L-246 Palmer Creek	241.8	0	66	0
L-246 Dalton Ditch	239.4	0	66	0
Tebbetts East LD	124.8	0	136	0
Howard Levee	124.4	0	137	0

[1]Calculated from attenuation analyses trend lines in Section 9
[2]Estimated from interpolated Missouri River flows based on river miles (includes lags)

Table 11.1.2 – Observed created-spring rises

Site	RM	Observed Created Spring Rise, ft		
		May-09	Mar-08	May-06
USACE Gavins Point Dam	811.1	1.4	1.3	
USGS Yankton	805.8	1.2	0.8	1.7
USACE Gayville	796	0.9	n.m.	1.7
USGS Maskell	775.6	1.0	1.0	1.6
Ponca State Park	753.4	-	1.1	-
USGS Ponca	751	1.6	1.4	2.7
USGS Sioux City	732.3	1.8	1.5	2.7
Hart's Lighthouse Marina	699.5	-	n.m.	2.6
USGS Decatur	691	1.6	1.4	2.7
Pelican Point	672.7	1.4	1.1	-
County Line Ditch	659	1.3	0.8	2.1
California Bend	650.6	0.3*	0	2.0
USACE Blair	648.3	1.4	1.1	2.2
McIntosh Levee	637.1	0.8*	0	0.5
USGS Omaha	615.9	1.4	1.1	2.2
La Platte	596.7	0.7	0.5	-
USACE Plattsmouth	691.5	0.7	0.5	1.8
Lake Wa Con Da	577.5	0.6	0.2*'	-
USGS Nebraska City	562.6	0.9	0.4	1.5
L-575 Structure No. 23	545.9	0.6	0	1.0
R-562/Peru	542.1	-	0.4	-
USACE Brownville	535.3	0.6	0.4	2
L-536 Structure No. 8	521.5	0.2*	0	1.2
USGS Rulo	498.1	0.6	0.4	1.5
Holt County LD No. 9	490.8	n.m.	-	1.4
R-500	480.2	0.5	-	-
L-497 Main Outfall	477.1	0.5	n.m.	1.4
L-488	472.8	n.m.	-	-
USGS St. Joseph	448.2	0.5	n.m.	1.4
L-448/443	428.4	0.5	-	-
R-440 Main Outfall	424.9	-	n.m.	-
L-408 Main Outfall	391.9	0.3	n.m.	-
USGS Kansas City	366.1	0.3	n.m.	1.1
USACE Napoleon	328.7	0.2	n.m.	0.9
MO Valley DLD	328.7	0.1	-	-
MO Valley LD No. 1	326.2	-	n.m.	0.8
USGS Waverly	293.4	0	n.m.	0.8
Cole Lake DD No. 2	277.1	-	n.m.	0.9
Brunswick Terminal	256.3	0	-	-
Dewitt DLD	255.3	0	-	-
Miami LD No. 1	252.1	0	-	-
Brunswick LD	250.3	0	-	-
L-246 Palmer Creek	241.8	0	0	0.4
L-246 Dalton Ditch	239.4	0	-	-
USACE Glasgow	226.3	0	n.m.	0.8

Howard County LD No. 6	221.2	-	n.m.	0.8
USGS Boonville	197.1	-	n.m.	0.7
USACE Jefferson City	143.9	-	n.m.	0.8
Capital View DD	141.4	-	n.m.	0.8
Tebbetts East LD	124.8	0	-	-
Mokane Levee	124.4	0	-	-
Tri-County LS Section No. 1	99.6	-	n.m.	1.4
Tri-County LS Section No. 2	99.6	-	-	1.7
USGS Hermann	97.9	-	n.m.	1.9

*Partial spring rise captured at the site (see glossary for explanation)
*'Rise reported in 2008 report was n.a. based on gage threshold problems. However, this is the partial rise captured by the gage at this site.
n.m. = not measureable

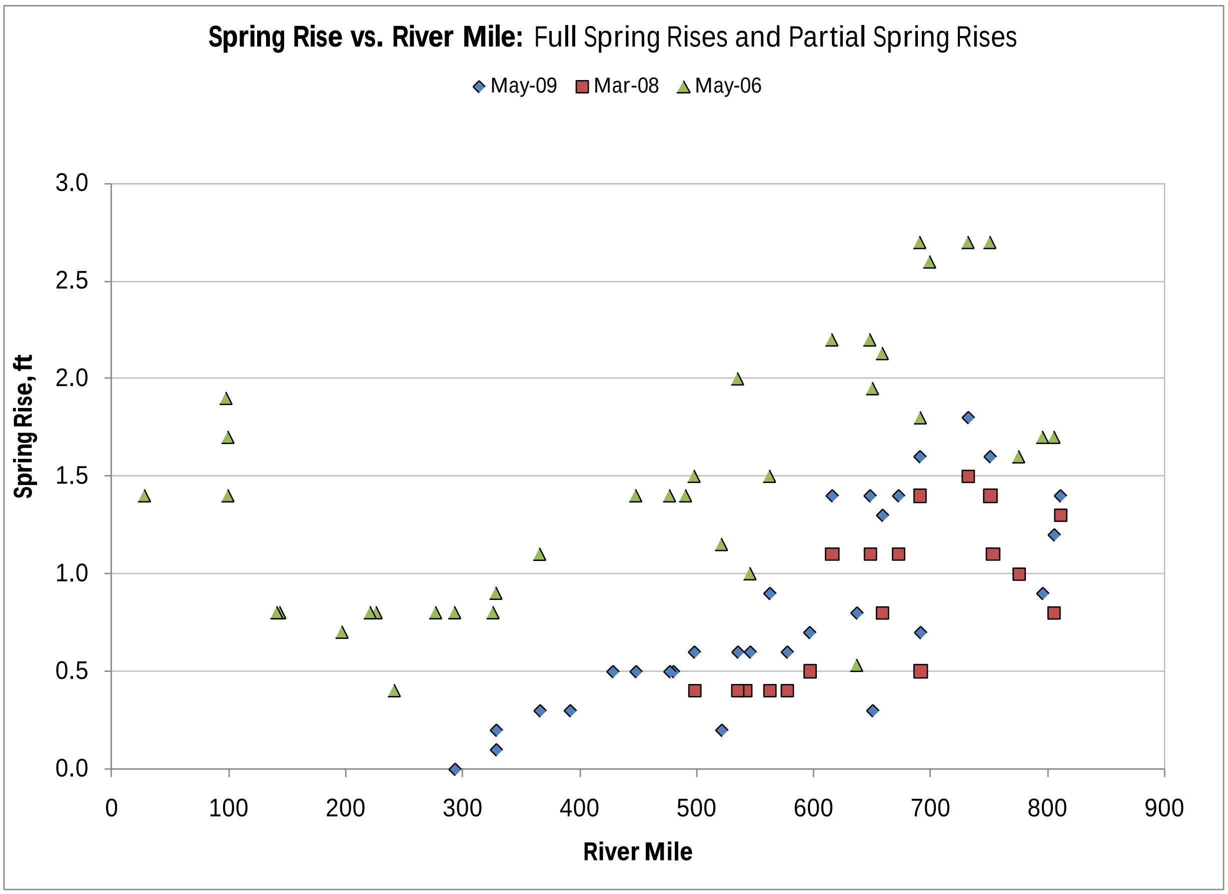

Figure 11.1.1 – Observed spring rises (May 2009, March 2008, and May 2006)

11.2 Natural Spring Rise Socioeconomic Impacts: Overbank Flooding

Table 11.2.1 lists monitored sites with overbank flooding in 2009. Flooding is separated into landside (LS) flooding and riverside (RS) flooding. Table 11.2.2 lists monitored sites with overbank flooding in 2008. This table does not include all the sites monitored in 2008 that might have experienced flooding, only the sites that were also monitored in 2009 and have surveyed field elevations. Table 11.2.3 shows sites where flooding was observed in the 2008 report. Only one site, Howard County LD No., was identified as having possible overbank flooding based on available information. In 2009, however, site records were reanalyzed where field elevations became available and two other sites were discovered to likely have overbank flooding. Shorter durations of flooding were observed in 2009 than in 2008. Figure 11.2.1 shows sites impacted by overbank flooding in 2009. Figure 11.2.1 shows sites socioeconomic impacts by overbank flooding in 2009. Figure 11.2.2 shows sites socioeconomic impacts by overbank flooding in 2008.

Table 11.2.1 – Overbank Flooding, 2009

Site	RM	LS Flooding, days	RS Flooding, days
L-575 Structure No. 23	545.9	0	0.5
L-536 Structure No. 8	521.5	0	0
L-488	472.8	8	n.a.
MO Valley DLD	328.7	2	1
Tebbetts East LD	124.8	Inconclusive	n.a.*

n.a. no field elevation provided on riverside of levee
n.a.* not applicable, site does not have riverside field to flood

Table 11.2.2 – Overbank Flooding (Updated), 2008

Site	RM	LS Flooding, days	RS Flooding, days
L-575 Structure No. 23	545.9	11	24
L-536 Structure No. 8	521.5	10	20

Table 11.2.3 – Overbank Flooding Estimated in 2008 Report

Site	RM	LS Flooding, days	RS Flooding, days
Howard County LD No. 6	221.2	9	0

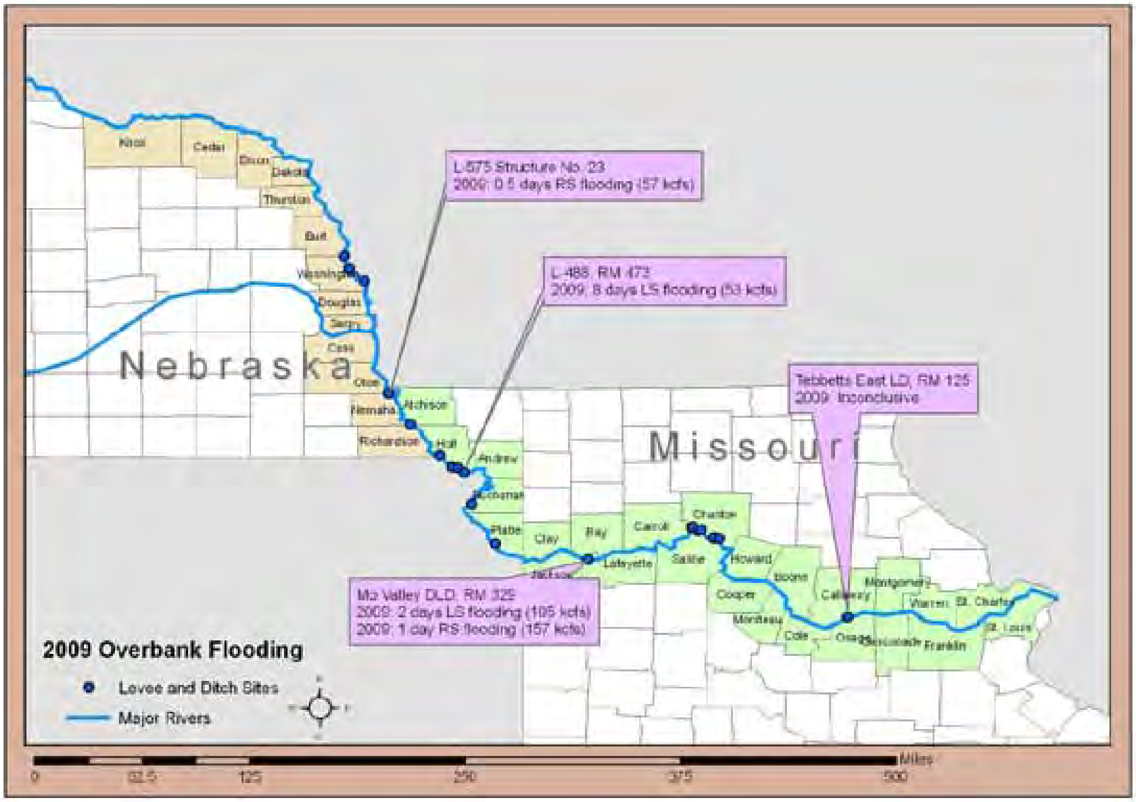

Figure 11.2.1 – Overbank flooding, 2009

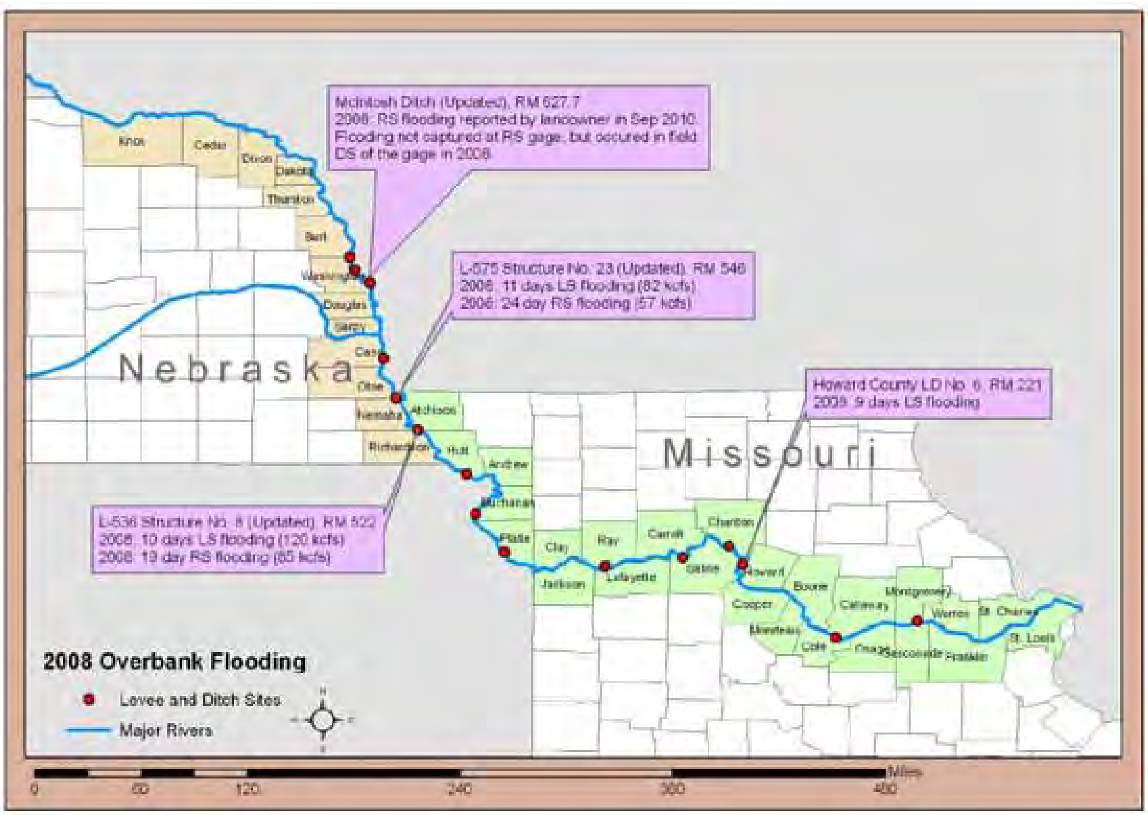

Figure 11.2.2 – Overbank flooding, 2008

11.3 Natural Spring Rise Socioeconomic Impacts: Pumping

Table 11.3.1 lists monitored sites with pumping in 2009. Table 11.3.2 lists monitored sites with pumping in 2008. The L-488 record had a lot of chatter and pumping might have occurred but is unlikely. Pumping occurred at site L-575 Structure No. 23 in both 2008 and 2009, but the total duration of the impact was 16 days shorter in 2009. Of the 8 monitored sites with pumps in 2009, 3 sites show evidence of pumping in response to high 2009 Missouri River flows. Four of the five sites with pumps in 2008 show evidence of pumping in response to high 2008 Missouri River flows. Note that L-536 Structure No. 8 has been removed from the list of sites that pumped in 2008 because surveyed field elevations indicate that overbank flooding occurred at the site and not pumping. Figure 11.3.1 shows sites that pumped in response to high flows in 2009. Figure 11.3.2 shows sites that pumped in response to high flows in 2008.

Table 11.3.1 – Pumping, 2009

Site	RM	Pumping, days	MR Estimated Impact Flow Threshold at Site, kcfs
L-575 Structure No. 23	545.9	0.2 – 7.4	51
Brunswick LD	250.3	3.7	88
L-246 Dalton Ditch SD	239.4	15	n.a.*

*Pumping occurred on a side ditch and was not directly affected by flows in the Missouri River
RM – River mile
MR – Missouri River

Table 11.3.2 – Pumping, 2008

Site	RM	Pumping, days
L-575 Structure No. 23	545.9	39
L-497 Main Outfall	477.1	16
R-440 Main Outfall	424.9	24
Cole Lake DD No. 2	277.1	36

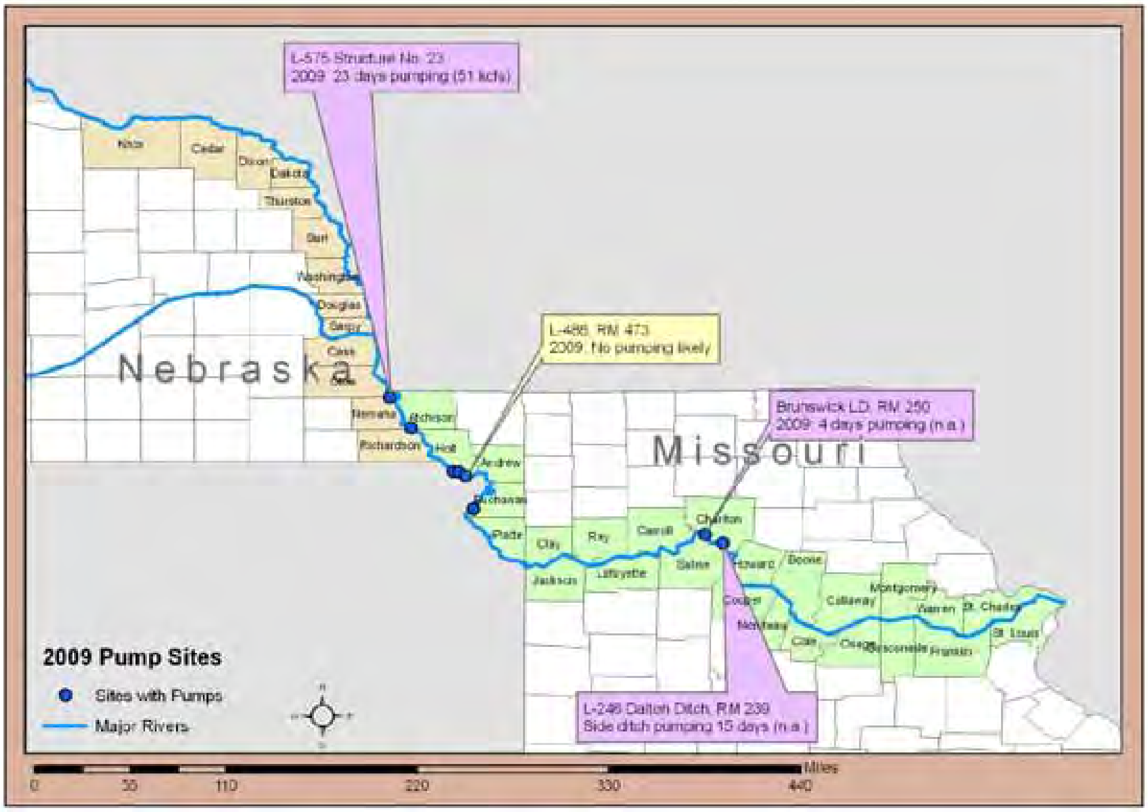

Figure 11.3.1 – Pumping in 2009

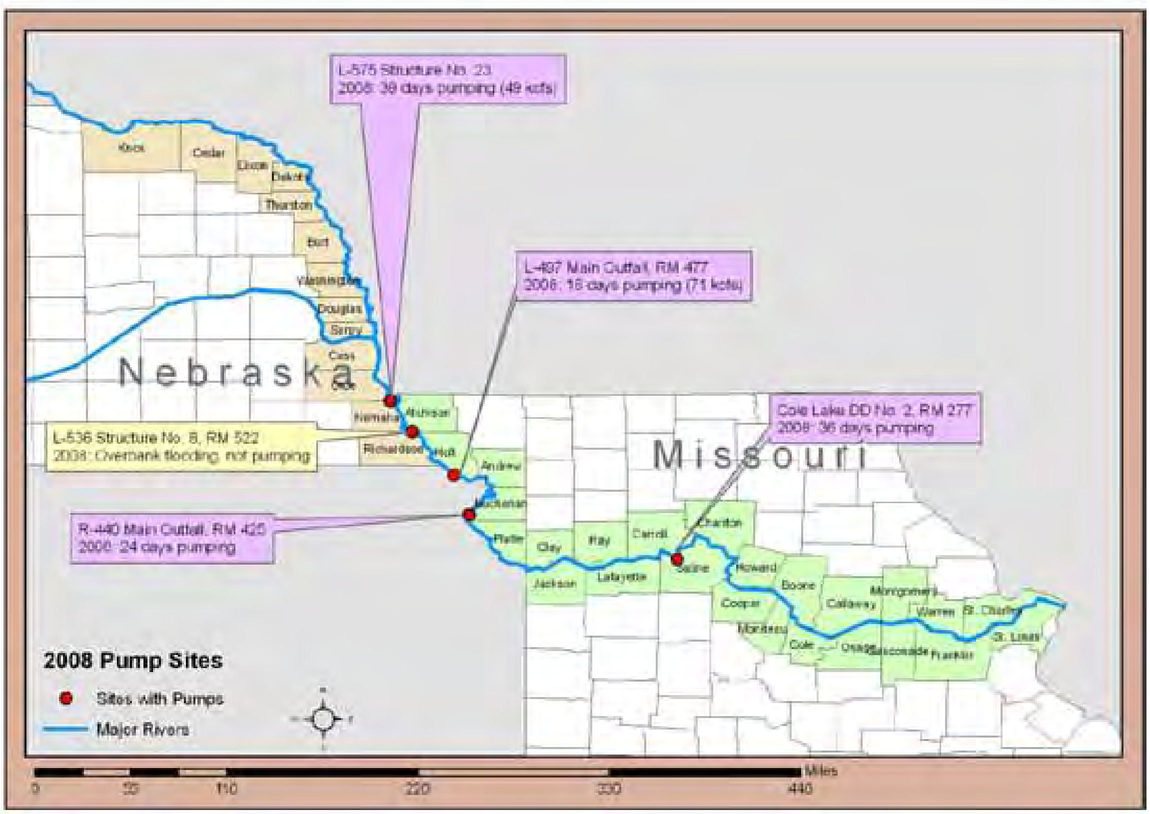

Figure 11.3.2 – Pumping in 2008

11.4 Natural Spring Rise Socioeconomic Impacts: Gate Closure

Table 11.4.1 lists monitored sites with gate closures in 2009. Table 11.4.2 lists monitored sites with gate closures in 2008. Of the 18 sites with either flap gates or manual gates in the 2009 study, 8 sites had gate closures in 2009. Of the 15 sites with either flap gates or manual gates in the 2008 study, 11 sites had gate closures. The total duration of gate closures in 2009 varied between 10 days to 45 days. The total duration of gate closures in 2008 varied between 19 to 39 days. The impact flow thresholds for monitored 2008 sites also monitored in 2009 were re-estimated to include flow lagging from the USGS gages to the site. Results are within 10% of the original estimate made in the 2008 monitoring report except in the case of the L-575 Structure No. 23 site.

Table 11.4.1 – Gate Closures, 2009

Site	RM	Gate Closure, days	MR Estimated Impact Flow Threshold at Site, kcfs	Impact Flow Threshold at US Gage, kcfs
L-575 Structure No. 23	545.9	10.5 – 12.3	51*	-
L-488	472.8	Inconclusive[1]	-	-
Missouri Valley DLD No. 1	328.7	0.1 – 4.1	100	90
Dewitt DLD	255.3	2.0 – 4.7	89*	89
Miami LD No. 1	252.1	1.3 – 4.9	82*	82
Brunswick LD	250.3	3.6 – 10	67*	67*
L-246 Palmer Creek MD	241.8	0.1 – 3.6	110*	110
L-246 Palmer Creek SD	241.8	0.4 – 6.5	n.a.[1]	n.a.[1]
L-246 Dalton Ditch MD	239.4	0.6 – 4.4	99	trib
L-246 Dalton Ditch SD	239.4	39	n.a.[1]	n.a.[1]
Tebbetts East LD	124.8	Inconclusive[2]	-	-
Howard Levee	124.4	2.6 – 5.6	216	trib

[1]Too much chatter in the record
[2]Gage location not close enough to CMP inlet
*Upstream USGS gage flow record lagged to site as estimate (impact flow threshold at site = impact flow threshold at US gage)
n.a.[1] not applicable because side ditch not directly affected by Missouri River flows
US – upstream

Table 11.4.2 – Gate Closures, 2008

Site	RM	Gate Closure, days	MR Estimated Impact Flow Threshold at Site, kcfs*
L-575 Structure No. 23	545.9	39	63 (49)
L-536 Structure No. 8	521.5	20	77 (76)
L-497 Main Outfall	477.1	22	71 (70)
R-440 Main Outfall	424.9	34	83
L-408 Main Outfall	391.9	19	94 (99)
MO Valley LD No. 1	326.2	20	89
Cole Lake DD No. 2	277.1	36	99
L-246 Palmer Creek	241.8	6.7 – 40	122 (118)
Howard County LD No. 6	221.2	2.8 – 33	134
Capital View DD	141.4	5.8 – 33	235
Tri-County LD Section 1	99.6	36	192

*values from 2008 monitoring report
( ) updated values determined in this report using lagging of flows and macro

11.5 Summary of Natural Spring Rise Socioeconomic Impacts, 2008 and 2009

Table 11.5.1 summarizes all the impacted sites in 2009 and 2008. Figure 11.5.3 shows the impacted sites in 2009 and 2008 plotted by their RM locations along the Missouri River and the estimated flows in the Missouri River at the sites that resulted in gage closures.

Table 11.5.1 – Natural spring rise impacted sites, 2008 and 2009

Site	RM	Monitored	2008 LS Flooding	2008 RS Flooding	2008 Pumping	2008 Gate Closure	2009 LS Flooding	2009 RS Flooding	2009 Pumping	2009 Gate Closure
County Line Ditch	659	2008 & 2009	N	N	-	-	N	N	-	-
California Bend	650.6	2008 & 2009	N	N	-	N	N	N		N
McIntosh Levee	637.1	2008 & 2009	N	N[1]		N	N	N[1]		N
L-575 Structure No. 23	545.9	2008 & 2009	Y	Y	Y	Y	N	Y	Y	Y
L-536 Structure No. 8	521.5	2008 & 2009	Y	Y	N[2]	Y	N	N	N	N
Holt County	490.8	2009					N		N	N
R-500	480.2	2009					N		N	N
L-497 Main Outfall	477.1	2008 & 2009	N		Y	Y	N		N	N
L-488	472.8	2009					Y		d.p.	d.p.
L-448/443	428.4	2009					N		N	N
R-440 Main Outfall	424.9	2008	x		Y	Y				
L-408 Main Outfall	391.9	2008 & 2009	N			Y	N			N
MO Valley DLD	328.7	2009					Y	Y	N	Y
MO Valley DLD No.1	326.2	2008	x	x		Y				
Cole Lake DD No. 2	277.1	2008	x	x	Y	Y				
Dewitt DLD	255.3	2009					N	N	N	Y
Miami LD No.1	252.1	2009					N		N	Y
Brunswick LD	250.3	2009					N		Y	Y
L-246 Palmer Creek MD	241.8	2008 & 2009	N			Y	N			Y
L-246 Palmer Creek SD	241.8	2009					N		N	s.l.
L-246 Dalton Ditch MD	239.4	2009					N		N	Y
L-246 Dalton Ditch SD	239.4	2009					N		Y	Y
Howard County LD No. 6	221.2	2008	Y			Y				
Capital View DD	141.4	2008	x	x		Y				
Tebbetts East LD	124.8	2009					d.p.		d.p.	d.p.
Howard Levee	124.4	2009					Y		N	Y
Tri-County LD Sect. 1	99.6	2008	N	N		Y				

Gray box means not monitored or not surveyed in the case of field elevations
d.p. data problem
x = no field elevation available to determine if flooding occurred, conclusively
[1]No impact captured in monitoring but evidence of drainage problems on RS of private levee in 2009
[2]Edited from 2008
s.l. stop log structure

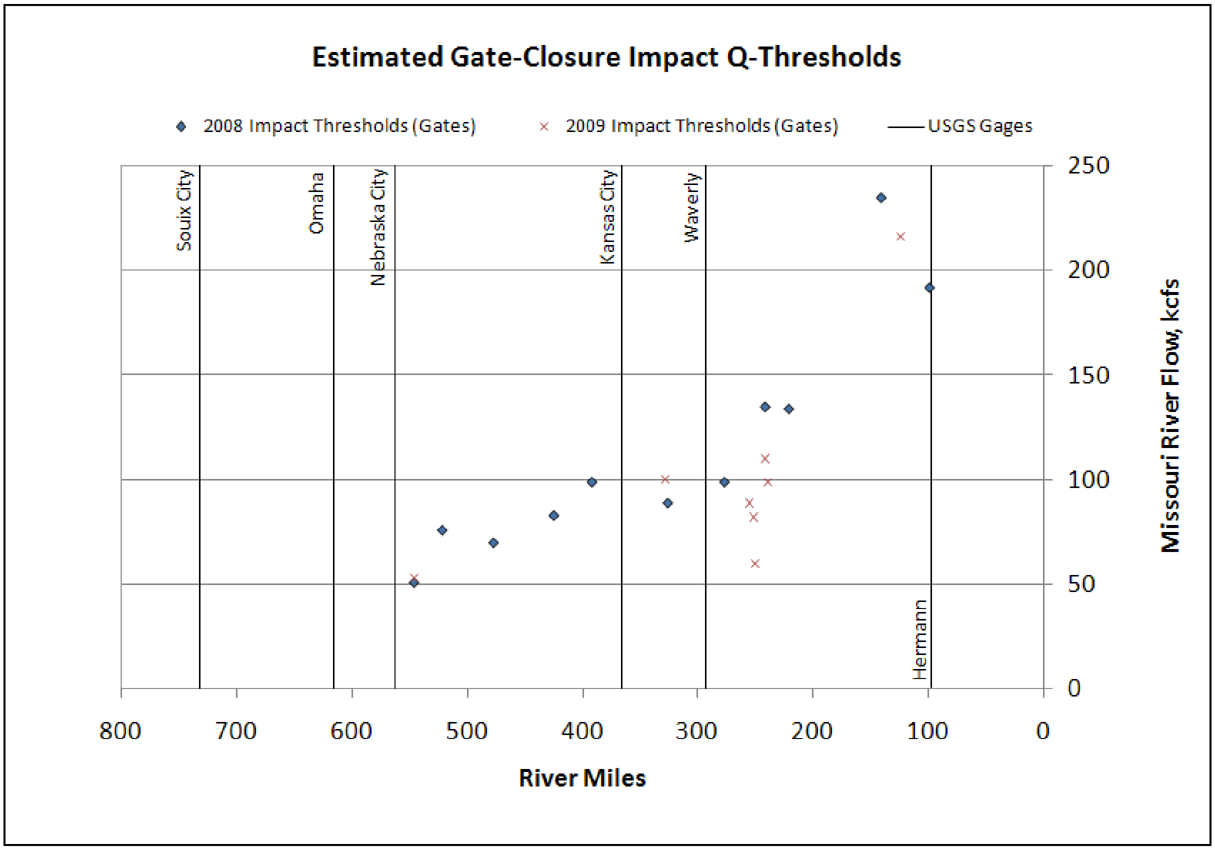

Figure 11.5.3 – Impact (gate-closure) flow thresholds, 2008 & 2009

12.0 Inlet and Outlet-flow Threshold Summary

Table 12.1 summarizes the outlet-flow thresholds estimated from the observed and interpolated flow records of 2009. Table 12.0.2 summarizes outlet-flow thresholds for sites monitored in both 2008 and 2009. Table 12.0.3 summarizes the inlet-flow thresholds estimated from the observed and interpolated flow records of 2009. Table 12.0.4 summarizes the inlet-flow thresholds estimated for sites monitored in both 2008 and 2009. Observed flows are from the closest US automatic gages with flow data to the site. The time lag from the US automatic gage to the site is considered. This means that if a site is 10 hours DS of an automatic gage, the gage record is lagged back 10 hours to determine what the flow passing the gage was when it passed the upstream automatic gage.

Table 12.0.1 – Outlet-flow thresholds, 2009

		Outlet-flow threshold, kcfs	
Site	Outlet Elev (ft msl)	Estimated MR Flows at Site	US Gage MR Flows
L-575 Structure No. 23	894.79	32*	32
L-536 Structure No. 8	869.14	d.p.*	d.p.*
Holt County	841.29	43	42
R-500	831.16	48	45
L-497 Main Outfall	830.74	62	58
L-488	824.05	51	47
L-448/443	780.6	51	46
L-408 Main Outfall	745.94	66	51
MO Valley DLD	695.31	58	55
Dewitt DLD	627.86	64*	64
Miami LD No. 1	627.02	66*	66
Brunswick LD	622.27	60	trib
L-246 Palmer Creek	616.5	64	trib
L-246 Dalton Ditch MD	612.96	64	trib
Tebbetts East LD	525.14	174	trib
Howard Levee	521.07	135	trib

d.p. data problem (typically, water surface elevations too high throughout monitoring)
d.p.* data problem, survey needed
n.m. not monitored
n.d. not determined
n.a. not applicable because the site drains into the Grand River and not directly into the Missouri River
*Same as flows at US gage because lagged to the site and not interpolated
trib – gage separated from US gage by large tributary inflows so the upstream gage value is not considered
US – upstream, MR – Missouri River, MD – Main ditch through levee, LD – Levee district

Table 12.0.2 – Outlet-flow thresholds, 2008 & 2009

Site	Outlet Elev (ft msl)	2008 Outlet-flow threshold, kcfs		2009 Outlet-flow threshold, kcfs	
		Estimated MR Flows at Site	US Gage MR Flows	Estimated MR Flows at Site	US Gage MR Flows
L-575 Structure No. 23	894.79	d.p.	d.p.	32*	32
L-536 Structure No. 8	869.14	d.p.*	d.p.*	d.p.*	d.p.*
L-497 Main Outfall	477.1	52	51	62	58
L-246 Palmer Creek MD	241.8	62	trib	64	trib

*Same as flows at US gage because lagged to the site and not interpolated
d.p. data problem, RS and LS water surface elevation too high to estimate
d.p.* data problem, need survey
trib – gage separated from US gage by large tributary inflows so the upstream gage value is not considered
MR – Missouri River

Table 12.0.3 – Inlet-flow thresholds, 2009

Site	Inlet Elev. (ft msl)	Inlet-flow threshold, kcfs	
		Interpolated MR Flows	US Gage MR Flows
L-575 Structure No. 23	895.96	36*	36
L-536 Structure No. 8	871.2	37	36
Holt County LD No. 9	841.64	43	42
R-500	833.13	58	53
L-497 Main Outfall	830.74	62	58
L-488	825.5	51	46
L-448/443	781.9	57	51
L-408 Main Outfall	747.28	75	51
MO Valley DLD	690.80	64	62
Dewitt DLD	629.26	71*	71
Miami LD No. 1	627.11	66*	66
Brunswick LD	623.42	61	trib
L-246 Palmer Creek	616.50	75	trib
L-246 Dalton Ditch MD	614.1	73	trib
Tebbetts East LD	525.26	179	trib
Howard Levee	522.37	143	trib

*Same as flows at US gage because lagged to the site and not interpolated
Trib – gage separated from US gage by large tributary inflows
MR – Missouri River, US – Upstream

Table 12.0.4 – Inlet-flow thresholds, 2008 & 2009

Site	Inlet Invert Elev. (ft msl)	2008 Inlet-flow threshold		2009 Inlet-flow threshold	
		Estimated MR Flows at Site, kcfs	US Gage MR Flows, kcfs	Interpolated MR Flows, kcfs	US Gage MR Flows, kcfs
L-575 Structure No. 23	895.96	37	-	36	-
L-536 Structure No. 8	871.20	37	33	37	36
L-497	830.74	52	51	62	58
L-246 Palmer Creek MD	616.50	69	trib	75	trib

13.0 Conclusions

13.1 Created Spring Pulse Conclusions

Conclusions concerning the spring pulse released from Gavins Point Dam for the benefit of the endangered pallid sturgeon follow.

§ The 19 interior-drainage sites monitored in 2009 were not impacted by the May spring pulse released from Gavins Point Dam for the benefit of the endangered pallid sturgeon.

§ Based on the flow-attenuation analysis, both the May 2009 and March 2008 created spring pulses attenuated at a similar rate (1.1 kcfs / 100 RM in March 2008 and 1.3 kcfs / 100 RM in May 2009). Although these rates are close to identical, attenuation will likely vary from year to year based on the depth of the base flow in the Missouri River, the storage available at that stage, and other characteristics of the channel.

§ Based on the attenuation analysis in terms of stage, the spring rise decreased at a general rate of 0.0035 ft/RM (0.4 ft / 100 RM) in May 2009. The March 2008 spring rise decreased at a general rate of 0.0043 ft/RM (0.4 ft / 100 RM) and the May 2006 spring rise decreased at a general rate of 0.0033 ft/RM (0.3 ft/ 100 RM).

§ Based on the attenuation equations, the 6.1-kcfs May 2009 spring pulse peak fully attenuated around RM 252 about 40 RM downstream of USGS Waverly (Table 9.1.4), and the 4.5-kcfs March 2008 spring pulse peak fully attenuated around RM 370 near the USGS Kansas City gage (Table 9.1.5).

§ Flow reductions were made from dams tributary to the Missouri River to eliminate the created spring rise below Kansas City, MO. Stage changes due to the created spring rise were still visible below Kansas City, but the created spring rise was only about 0.3 ft by Kansas City in 2009, and its elevation in the Missouri River had been decreased by 2 to 3 ft.

§ The observed stage change in the Missouri River due to the May 2009 created spring rise was estimated at each site and became indistinguishable by USGS Waverly (RM 293).

§ The created spring rise accounted for about 27% of the total Missouri-River peak flow at Gavins Point Dam (observed), 16% of the total peak flow at Pelican Point (RM 673), 9.8% of the total peak flow at L-575 Structure No. 23 (RM 546), and 0% of the total peak flow at USGS Glasgow. The peak flow of the created spring rise was calculated based

on the results of the attenuation analysis in Section 9. These peak flows were then compared with the observed or interpolated flow of the Missouri River at the same river mile. Note that attenuation values are estimates based on observed data.

13.2 Natural Spring Pulse Conclusions

Conclusions concerning natural spring pulses observed in the monitoring record follow.

§ The 2008 record experienced a long-duration large natural rise that began in late May and continued through mid-June or early July depending on the river location. In contrast, the 2009 record experienced several shorter duration rises scattered through the record. See Section 3 for details.

§ Table 13.2.1summarizes impacts for the created and natural spring rises in 2006, 2008, and 2009. Natural spring rises were not monitored in 2006. The same number of sites was impacted in 2009 and 2008 but the durations of the impacts were shorter in 2009.

Table 13.2.1 – Summary of Impacts

	Monitoring Period		
	2009	**2008**	**2006**
No. Interior Drainage Sites Monitored	19	16	7
Created Spring Pulse Released from Gavins Point Dam			
No. Interior Drainage Sites Impacted by Created Spring Pulse	0	0	0
Natural Spring Rises			
No. Interior Drainage Sites with Impacts	11	11	-
Days of Impacts	0.5 to 12	6.7 to 39	-
No. Interior Drainage Sites with LS Flooding	2	3	-
Days of LS Flooding	1.8 to 2.7	9 to 11	-
No. Interior Drainage Sites with RS Flooding	2	2	-
Days of RS Flooding	0.5 to 1	20 to 24	-
No. Interior Drainage Sites with Gate Closures	8	11	-
Days of Gate Closures	0.1 to 11	6.7 to 39	-
No. Interior Drainage Sites with Pumping	3	4	-
Days of Pumping	0.2 to 12	15 to 39	-

14.0 References

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